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Development of the SETIS Instrument to Measure Teachers' Self-Efficacy to Teach Science in an Integrated STEM Framework

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I am submitting herewith a dissertation written by Monica Clutch Mobley entitled "Development of the SETIS Instrument to Measure Teachers' Self-Efficacy to Teach Science in an Integrated STEM Framework." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Teacher Education.

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Development of the SETIS Instrument to Measure Teachers' Self-Efficacy to Teach Science in an Integrated STEM Framework

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DEDICATION

To John Mobley with love and gratitude for your patience and encouragement,
but mostly for being my Best Friend,
and,
To my father, David Chappell Clutch, who believed in me.

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ABSTRACT

Integrated STEM teaching and learning has gained increased attention in recent years as schools try to prepare students for 21st century careers. Goals of integrated STEM teaching are in alignment with goals of science education reform efforts as evident in recent document such as the Next Generation Science Standards (Achieve, Inc., 2013) and efforts are underway to encourage science instruction from within an integrated STEM framework. Teaching science content in an integrated STEM context is a complex act placing great cognitive and emotional demands on teachers, many of whom lack experience with this manner of teaching and may also lack the content knowledge necessary to navigate multidisciplinary requirements associated with integrating STEM subjects. One of the strongest predictors of a teachers' coping behaviors as well as both amount and duration of effort put into an action/task in the face of challenges is self-efficacy (Bandura, 1997). Adequately training and supporting teachers implementing science instruction within an integrated STEM framework therefore requires an understanding of the nature of those factors that establish teacher self-efficacy to teach in this way. The purpose of this mixed-methods study was twofold: (1) To develop an instrument with acceptable validity and reliability for the measurement of the latent factors describing science teachers' self-efficacy to teach science within an integrated STEM framework, and (2) identify the constructs that define teacher self-efficacy to teach science within an integrated STEM framework. An exploratory factor analysis produced a three factor solution with 19-items maintained in the model. The instrument was named the SETIS Instrument and it demonstrated acceptable validity and reliability ($r > .878$). The final model was largely supported by qualitative open-ended survey responses and interviews which also were able to identify specific constructs that determine teacher self-efficacy to teach science in an integrated STEM framework. Further

development of the SETIS Instrument should be undertaken given some inconsistencies between qualitative and quantitative results. It was concluded however that the SETIS can be useful in guiding pre-service and professional development for integrated STEM science teaching.

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CHAPTER I - INTRODUCTION AND LITERATURE REVIEW

Context for STEM Education

Current economic conditions support national interest in talent development in the areas of science, technology, engineering, and mathematics (STEM) with 16 of 24 projected high growth job sectors for the near future residing within STEM fields (NRC, 2010). Future economic expansion relies heavily upon jobs created directly and indirectly by advances in science and technology (Augustine et al., 2010, p.18), yet fewer U.S. students are graduating in STEM careers (NSB, 2010). As a result, the U.S. relies increasingly upon foreign-born talent (NSB, 2010) in the face of widespread competition from countries rapidly expanding in innovation-related markets (Augustine et al, 2010; NSB, 2010). The necessity of innovation toward achieving economic and personal well-being is widely recognized (Augustine et al, 2010; NSB 2010; NRC, 2010a, b), and innovation requires creativity, determination (NSB, 2010) critical thinking, and problem-solving abilities (Duschl, Schweingruber, & Shouse, 2008; NRC, 2010).

Accepted as fundamental to the development of an innovative domestic workforce is improvement of science and math education in the U.S. as well as efforts to engage students in STEM opportunities in rich and meaningful ways; ways that encourage sustained interest leading to increased numbers of U.S. schoolchildren eventually entering and graduating in STEM disciplines (Augustine et al., 2010; NRC, 2010a, b, NSB 2005, 2010). Consistent with an increasingly diverse population, efforts to attract students to STEM careers includes focus on under-represented minority students and students from socioeconomically disadvantaged populations (Haak, HillRisLambers, Pitre, & Freeman, 2011).

While this dissertation focuses upon career-preparation aspects of the STEM education movement, considering the common invocation of international testing as the driving force behind neo-modern arguments for promotion of STEM education, it seemed prudent to present that discussion. A widely held position on reasons for the importance of STEM literacy as well as efforts to implement STEM education opportunities, circulates around the argument that U.S. students under-perform in comparison to their counterparts in other industrialized nations. Most recently, a ranking of 36th in math and 27th in science out of 65 nations participating in the 2012 Program for International Student Assessment (PISA) given to 15-year olds worldwide (Organization for Economic Cooperation and Development [OECD], 2013) was earned by U.S. students. The subsequent concern offered in the context of an urgency toward production of science, mathematics, and engineering professionals in the U.S. which arose during the 1950's Cold War/Sputnik era, is a perceived *lack* of progress. This position argues that despite intense attention to science education reform, U.S. students have shown virtually *no* improvement in math literacy and only a slight, arguably negligible one-time improvement in science literacy since the resurgence of calls for reform outlined in Science for All Americans (American Academy for the Advancement of Science [AAAS], 1989), a part of the Project 2061 initiative.

Further indicated are similar outcomes on another major international comparison, the Trends in International Math and Science Study (TIMSS), which assesses fourth and eighth grade students and was most recently conducted in 2011. While fourth grade students were in the top 15 of nations, this placement dropped to a top 23 position by eighth grade. Further positional decline on the PISA suggests that as students advance in grade level, some factor or combination of factors are preventing U.S. students from achieving equal or greater levels of achievement compared to other economies, most notably those Southeast Asian countries such as

Shanghai-China, Singapore, and South Korea which all consistently score near the top in international assessments of math and science literacy. All the while, education reform efforts have sought means of counteracting the factors that confound attempts to better align U.S. global dominance and U.S. educational goals for international dominance.

Whether one adopts the changing global science-engineering technocracy argument as central to this dissertation or the international competition position described, science education reform is fundamental to understanding the nature of efforts to move students toward, and retain student in STEM careers. At the forefront of transformative efforts from the outset has been science education reform spearheaded largely by the National Science Foundation (NSF) and the AAAS followed by their many subsidiaries and associations such as the NRC, NSB, and others. Combined with reform work in other disciplines, most notably mathematics education reform (National Council of Teachers of Mathematics [NCTM], 1989) and complemented by recent pushes to include technology (Technology for All Americans Project, & International Technology Education Association [ITEA], 2000) and engineering education (Carr, Bennett, & Stroebel, 2012; Council, 2009) into PK-12 education has emerged the field of STEM education (Breiner, Harkness, Johnson & Koehler, 2012).

While the vision for STEM education appears promising in prestigious reform documents (Kuenzi, Matthews, & Mangan, 2006), debate about what STEM means and evidence on fidelity of implementation in science classrooms is scarce. One of the possible factors that may have a strong effect on fidelity of implementation of any curriculum program is teachers' self-efficacy, or confidence in ability to teach science through STEM integration. The purpose of this study, therefore, is to explore science teachers' self-efficacy to teach science within an integrated STEM framework.

Regardless of the infancy of integrated STEM education as an instructional framework, STEM education has grown substantially in recent years as evident in the most recent report on STEM education programs by the Government Accountability Office [GAO], (2010), revealing that 13 agencies invested over $3 billion in 209 programs targeting specifically the increase of knowledge of STEM fields and increasing the number of students achieving STEM degrees (p. 1). The 2011 federal budget for STEM education alone, absent other STEM allocations, was $3.7 billion, with an additional $4.3 billion ear-marked toward *Race to the Top,* which prioritizes STEM in funding decisions (Breiner et al., 2012, p. 5).

With so much emphasis on STEM education it can be predicted that ever-increasing numbers of teachers will be called upon to adopt this framework for teaching and learning. Integrated STEM goals promote authentic experiences reflecting the evolving nature of sciences. Science has always been reliant upon mathematics as an explanatory tool. Increasingly, science has expanded its interdisciplinary range requiring practitioners to navigate engineering, computational sciences, new technologies, and to acquire communication skills necessary to access data and resources from other research and career professionals. These are demanding aptitudes for teachers to both possess and be able to instill in their students, and may present challenges affecting teacher willingness to attempt and persevere adopting integrated STEM teaching and learning formats. Following Bandura's (1997) description of beliefs about capacity to successfully perform an activity or task as "self-efficacy", this research emphasizes the importance of self-efficacy in resulting "doing". Thus understanding the knowledge, skills, resources, and support teachers need to develop the self-efficacy to persevere in a potentially challenging teaching and learning environment are justified as important research goals, yet to this day no research measuring self-efficacy to teach integrated STEM exists. Indeed, to date there has been no clear identification of those constructs that indicate measures of self-efficacy to teach integrated STEM.

With science as the content area of interest, this investigation calls for development of an instrument to measure science teachers' perceived self-efficacy to teach their content from within an integrated STEM framework. A discussion of STEM and integrated STEM follows in order to develop the context directing the research goals.

STEM Defined

In response to reform recommendations and to address the need for innovative thinking by U.S. students have risen science, technology, engineering and mathematics (STEM) initiatives in education as focal points for exposing students from diverse backgrounds to STEM opportunities (Haak et al., 2011). Exposure opportunities correspond with a broader goal of fostering lasting interest in STEM careers (Augustine et al., 2010; Kuenzi, et al., 2006; NRC, 2010; NSB, 2010). Concurrent necessary skillsets for U.S. competitiveness have been described as "21st century skills" which include such characteristics as adaptability, complex communication, novel problem-solving, systems-based thinking, social discourse skills and self-regulation (Bybee, 2010; National Commission on Mathematics and Science (2000); NRC, 2010; NSTA, 2008). 21st century characteristics allow individuals to navigate a global, technology-oriented world in which reasoning skills for problem analysis and decision making, communicating in multiple contexts using multiple formats, evaluating and synthesizing information from various sources, self-directed and self-regulatory behaviors in work and management situations, and working with others to share knowledge and ideas in a culturally sensitive way are all viewed as key personal attributes (Beers, 2013). It has been argued that 21st century knowledge, habits of minds and skillsets can be promoted more effectively through an integrated STEM curriculum (Berlin & Lee, 2005; NAS, 2013). Currently, the American Association for the Advancement of Science, International Technology Education Association, National Council of Teachers of Mathematics, National Research Council, and National Science Teachers Association all recommend mathematics and science integration (Berlin & Lee, 2005, p.15) as well as integration with engineering and computational thinking (Breiner et al., 2012). STEM education reform documents share recommendations for integration of mathematics and science but include engineering and technology in the equation (NAS, 2013; NSB 2010).

The question arises then, if STEM education is a means of moving students toward acquisition of knowledge and skills needed to become productive members of a 21st century society, what exactly is STEM education and how does it achieve these goals? While STEM has been in education and policy since the 1990's, the definition remains inconsistent, having been influenced over the years by context, politics, and stakeholders in question (Breiner, et al., 2012). Studying the origin of the definition demonstrates some of these shifts in meaning and intent over time. Therefore, providing some history grounded in science and mathematics education literature merits discussion, and is the focus of the following section.

STEM History

STEM first debuted as the acronym "SMET" for science, mathematics, engineering and technology from within the NSF, though this was shortly thereafter changed to "STEM" following complaints that "SMET" was overly akin to "SMUT" (Sanders, 2009, p.20). This new acronym has provided problems of its own from confusion regarding potential association with botany (Angier, 2010; Sanders, 2009) which has a natural inclination to interpret "STEM" as an important plant part. Alternatively, but equally troubling, is the fact that a Google search of STEM education automatically includes hundreds of papers in the field of stem cell research.

Associated unintentional anomalies created through adoption of this acronym are best presented by Bybee (2010, p. 30) who writes:

> "*Botanical scientists were elated, as they thought educators had finally realized the importance of a main part of plants. Technologists and engineers were excited, because they thought it referred to part of the watch. Wine connoisseurs were enthusiastic, as they thought it referred to the slender support of a wine glass. And, political conservatives were worried, because they thought it was a new educational emphasis supporting stem cell research."*

While it may seem appropriate to scoff at these early, retrospectively humorous associations, as STEM has become normalized in education circles, a singular definition remains problematic due to the possibility, indeed the necessity, of multiple interpretations. As just one example, beyond simply 'STEM' education there now exist 'STEAM' education, which is an attempt to insert an 'A' for 'Arts' into the already complex STEM equation, a consideration beyond the current scope of this paper. Not considering the addition of yet more disciplines, this paper will argue that a single, concise definition of STEM is increasingly problematic once different models (Johnson, 2012, Roehrig, Moore, Wang, & Park, 2012; Sanders, 2009) of STEM education are introduced in a variety of contexts.

Broadly, STEM education is defined as education in the areas of science, technology, engineering and mathematics, though the ambiguity of this definition becomes immediately apparent considering all possible configurations of these four disciplinary areas and potential meanings (Breiner, et al., 2012). Breiner et al., (2012) note a relationship between definition and perspective, with policy perspectives and education perspectives being distinct relative to emphasis on integration of STEM content, an important distinction since this paper accepts the

STEM orientation from an integrated perspective, despite being oriented toward education. Despite most scientists (Breiner et al., 2012) and educators understanding that STEM refers to science, technology, engineering, and mathematics, many have a practical conceptualization centered on only math and science (Bybee, 2010).

Unsurprisingly, there are various approaches to fulfilling such a tenuous definition including providing stand-alone coursework in each discipline, providing varying degrees of cross-curricular connections, or providing elective or extracurricular courses that attempt to approach some combination of the four disciplines in a consolidated manner (Johnson, 2012).

Ambiguity in definition, regardless of merit, has resulted in a variety of STEM program formats emerging from various stakeholders as they attempt to negotiate political and societal demands for improved U.S. student performance on international assessments, provision of opportunities for students to participate in and develop interest in STEM disciplines, increasing numbers of U.S. nationals in STEM careers, and improving the quality and availability of STEM teachers (Kuenzi et al., 2006; NAS, 2013). Across the nation, districts have undertaken a variety of actions to address the need for improved STEM education from the development of STEM-dedicated stand-alone schools to comprehensive schools with STEM initiatives within their improvement plans. The National Science Foundation (NRC, 2010, p.4; NRC, 2011) identified goals of STEM education as increasing advanced training and careers in STEM fields, expanding the STEM-capable workforce, and increasing public science literacy: *goals many school districts have held in kind for years*. Intermediate goals identified by the NSF (2010, p.4) are indicative of the important role and thus prioritization of public education in achieving the renewed national push to achieve STEM objectives, these goals being teaching and learning of STEM content and practices, development of positive dispositions toward STEM, and preparing students to be lifelong learners; objectives that can only be fulfilled from within educational systems.

STEM Models

One of the most important questions in STEM education today is "what is being taught, when and how?" This question centers on existing variability in configuration of disciplinary areas and emphasis in pursuit of science and mathematics education reform goals. Given four distinct disciplinary content areas, national, state and district achievement goals and expectations along with testing pressures requiring that specific content are included for school and teacher scoring purposes; there emerges a surfeit of potential configurations in which STEM can be taught. Indeed, pressures on school systems to develop STEM programs and acquire external STEM funding, which is heavily dependent on consistency with current political goals for education (Breiner et al., 2012) creates a marketplace for innovation in STEM education. An unfortunate side-effect of innovative program development can be confused purpose and lack of coordination along with inconsistency relative to how STEM programs are to fit into mainstream education (Kuenzi, et al., 2006). Unsurprisingly, in response to the offering of federal and state dollars for innovative STEM programs, schools have scrambled to propose schools, courses, and programs directed at achieving STEM goals. A range of approaches to STEM education now exist with varying degrees of merit associated with each approach. In the subsequent section of the paper I describe and elaborate upon the most common STEM models discussed in STEM education literature.

Common STEM Models

Science education reform documents make consistent reference to interconnectedness of science with other disciplines (Achieve, Inc., 2013; CCSSI, 2013; NRC, 2011, NSB, 2010 a,b) using terms such as ‘cross-cutting,’ ‘interdisciplinary,’ and others. Commonly invoked are the terms ‘multidisciplinary’, ‘transdisciplinary’, ‘interdisciplinary’ and now ‘integrated’. These terms are frequently used interchangeably (Dyer, 2003; Rosenfield, 1992) though their definitions are distinctly different in meaning and when implemented, in context (Wall & Shankar, 2008).

Multidisciplinary STEM education. Multidisciplinary STEM education is arguably one of the earliest approaches to STEM education. The term “multidisciplinary” can be explained as a “mixture” of disciplines. This is probably best defined by Lederman and Niess (1997) who compare tomato and chicken noodle soup. Their definition for “multidisciplinary” was established as analogous to chicken noodle soup where each ingredient (chicken, noodles, peas, carrots) maintains its own unique identity. Within an educational paradigm, this would insinuate that students would, as Lederman and Niess (1997) propose, be able to distinguish “doing” science from “doing” math, or “doing” any other discipline. In other words, each discipline maintains its own separate identity despite other disciplines being taught concurrently across the lesson. In such a scenario, a science teacher may include math and/or engineering, and/or technology in a single lesson, but each will retain a distinct content and curricular focus. Multidisciplinary STEM education may even involve different team members working on different aspects of a problem with each team member assigned a disciplinary-centered contribution (Wall & Shankar, 2008). In this case, communication skills between team members are a key attribute and overshadow collaboration in problem-solving (Park & Son, 2010). It has also been established that curriculum, coordination of planning, and commitment to approach are key to success or failure in multidisciplinary programs (Wicklein & Schell, 1995).

Transdisciplinary STEM education. Transdisciplinary STEM education, as the prefix "trans" implies, seeks to rise above a single discipline and transcend into a common place focused on resolving larger world problems (Lantz, 2009; Morrison, 2006, Park & Son, 2010). It has been defined as focusing upon issues across, between, and beyond learning areas to promote new, broader perspectives and deeper understanding of interrelatedness of complex issues (International Baccalaureate Organization, 2010, p.11). Wall & Shankar (2008) further describe transdisciplinary approaches to education as valuing knowledge and skill contributions of individual team members, requiring sensitivity to blurred boundaries in terms of disciplinary importance, and requiring intense collaborative organization on the part of the teacher to ensure each student has a defined role. Blurring boundaries between disciplines is a primary goal of transdisciplinary approaches to education in order to achieve disciplinary authenticity (Park & Son, 2010).

Transdisciplinary approaches have been criticized as being subject to disciplinary disconnect due to a lack of strong affiliation with any single disciplinary framework (Wall & Shankar, 2008). This approach may also present difficulties in that students may not meet disciplinary-specific achievement requirements based upon lack of attention to single-disciplinary standards and failure to achieve to deep understanding of disciplinary content since breadth of disciplinary approach may compromise depth of specific content understanding (Morrison, 2006). To achieve STEM education goals, knowledge of disciplinary content and how disciplinary practices do not occur in isolation of other disciplines (Breiner et al., 2012) is necessary. Interdisciplinary STEM education, discussed next, precludes transdisciplinary approaches in fulfilling this need.

Interdisciplinary STEM education. Interdisciplinary STEM education is broader in terms of relation to other disciplines than multi- and transdisciplinary approaches in that it intentionally attempts to include all four STEM disciplines, though each discipline can be identified as a separate entity by students participating in learning activities (Frykolm & Glasson, 2005; Morrison, 2006). Park and Son (2010) emphasize the significance of this difference relative to the knowledge produced by trans- versus inter- disciplinary projects. Transdisciplinary learning is focused upon knowledge production as produced in a participatory way with level of participation determining learning outcomes. Interdisciplinary learning situates students as knowledge collaborators and is learner collaboration driven (Park & Son, 2010) since no single student possesses the full range of knowledge necessary to conclusively appropriate a given research question. Interdisciplinary learning relies upon social construction of knowledge, so its activities direct students to collaborate and communicate individual findings and integrate these findings into a final product using knowledge and practices from multiple disciplines (Wall & Shankar, 2008). Interdisciplinary STEM may additionally attempt to bring other disciplines into the STEM program such as the arts, music, and language arts (Johnson, 2013) however, inclusion of other disciplines into STEM is not a focus of this research.

Integrated STEM education. Further confusing understanding of what is meant by various models of STEM education is the fact that the terms interdisciplinary and integrated are often used interchangeably, and one view is that an interdisciplinary approach is just one type of integrating STEM (Wang, Moore, Roehrig, and Park, 2010). Truly integrated STEM education seeks to combine science, technology, engineering, and mathematics into a single class focused on connections between the subjects and real world problems (Moore, 2008 in Wang, Moore, Roehrig, and Park, 2010; Stohlmann, Moore, & Roehrig, 2012). Or more simply put, integration implies students are taught in a way emphasizing interconnectivity and applications linking all STEM subjects (Fogarty, 1991; Frykholm & Glasson, 2005; Stohlmann et al., 2012) such that subjects being integrated are no longer distinctly delineated into unique disciplines. More frequently, however, integrated STEM education takes many forms and may span multiple classes, use multiple teachers, and may not necessarily involve all four STEM disciplines (Moore, 2006; NAS, 2013; Stohlmann, etal., 2012). Problematic definition of integrated STEM is directly related to the fact that integrated STEM teaching and learning can assume a wide variety of forms and yet still be considered "integrated" which is why the most recent publication of the National Academy of Sciences [NAS] (2013) chose to develop a framework for integrated STEM education rather than attempting to develop a definition. The framework is attentive to specific planning, resources, implementation challenges, and outcomes associated with integrated STEM teaching and learning. Accordingly, the framework is broken into four categories: (1) goals of integrated STEM education, (2) outcomes of integrated STEM education, (3) nature and scope of integrated STEM education, and (4) implementation of integrated STEM education (p.31). Interestingly, assessment was not included in the framework, but will be addressed in the discussion section of this research document.

General consensus supports integrated STEM as a meaningful approach to STEM education (Breiner et al., 2012; Bybee, 2010; Project Lead the Way, 2005; Sanders, 2009; Smith, Douglas & Cox, 2009; Stohlmann et al., 2012). Additionally, many national, state, and district programs broadly invoke the term 'integrated STEM'. Combined with increasing efforts to implement integrated STEM into K-12 classrooms, it seems prudent to establish a working definition for integrated STEM.

This paper proposes the following definition of integrated STEM: Integrated STEM is an approach to teaching and learning in which any combination of the four major STEM disciplines are taught in a manner such that the curriculum and content of the individual disciplines seamlessly merge into real-world experiences contextually consistent with authentic problems and applications in STEM careers. Such integration includes close and intentional attention to the inclusion of core disciplinary practices of each STEM domain being integrated, and purposeful attempt to make meaningful connections between the core concepts of each discipline, with the goal of using this integrated knowledge to solve real-world problems.

This definition was developed after reviewing recent reform documents such as NGSS and existing literature on integrated STEM education. Concerns about depth versus breadth of content learning (Berland & Busch, 2012; Morrison, 2006) supported a move away from the requirement that all four STEM disciplines be included at all times in order for the lesson to qualify as integrated STEM. STEM careers have fluctuating emphasis on specific disciplines depending upon the problem at hand, (NSB, 2010) and this definition seeks to mirror fidelity to authentic career conditions. Following this fidelity to authenticity, the second part of this definition addresses importance of student development of knowledge and skills consistent with seamless integration of disciplines as they are used to explore real world problems and applications (Fogarty, 1991; Frykholm & Glasson, 2005; Moore, 2008; in Wang, Moore, Roehrig, and Park, 2010; Stohlmann, Moore, & Roehrig, 2012).

Integrated STEM Emphasis

Having established a functional definition for integrated STEM, it is possible to shift attention back to a larger question: Why the current emphasis on integrated STEM education? Focus on integration is likely emergent from long-standing support for the integration of science and mathematics teaching and learning, which has been commonly promoted since 1905, with an upsurgence of integration literature occurring between the 1960's and 1970's and more than doubling in each subsequent decade (Berlin & Lee, 2005). A review of national education reform documents recommending integration of science and mathematics identified the American Association for the Advancement of Science (AAAS), International Technology Education Association (ITEA), National Council of Teachers of Mathematics (NCTM), National Research Council (NRC), and National Science Teachers Association (NSTA) as important proponents (Berlin & Lee, 2005; NAS, 2013). Since then, advocacy for integration has moved to STEM education (NAS, 2013; Scholmann et al., 2013) for multiple, yet connected reasons.

STEM learning and workforce needs. Integrated approaches to K–12 STEM education are being promoted consistent with the argument that teaching STEM in a more connected manner, in the context of real-world issues, can make the STEM subjects more relevant to students and teachers, build motivation for participation in STEM activities and careers, and develop the skillsets deemed necessary for a modern workforce (Brown, Brown, Reardon, & Merrill, 2011; NAS, 2013).

Breiner et al. (2012) support the position that simply including a disciplinary area is not enough to develop authentic, deep understandings of STEM. They note the tendency for STEM curriculum to fail to provide consistency between how STEM is *taught* and how STEM is *done* in "real world" scenarios, which confound student appreciation of the relevance of STEM to their daily lives. True integration of STEM disciplines into a single purpose is important considering that "boundaries between STEM subjects in school have been found to limit students' learning through the low transferability of knowledge between different cognitive contexts" (Tuomi-Grohn and Engestrom, 2007, in Hardy et al., 2008, p.1). Furner and Kumar

(2007) describe separate subject curriculum as a “jigsaw puzzle without any picture” (p. 186), supporting Frykholm & Glasson’s (2005) position that student problem-solving ability is often compromised by a lack of understanding of the context in which problems are situated.

STEM and quality of learning. Benefits of integrated teaching and learning have been documented in several disciplines. A comparative study of 211 undergraduate college algebra students by Elliot, Oty, McArthur, and Clark (2001) measured differences in student outcomes related to problem-solving skills, critical thinking skills, and attitudes towards mathematics in a traditional college algebra course versus an interdisciplinary course in which science topics were connected to science content and context being used to introduce mathematics topics. While no significant differences existed in problem-solving outcomes, students in the interdisciplinary course showed slightly larger gains in critical thinking and significantly more positive attitudes toward mathematics, an important finding given that a major goal of STEM education is to achieve positive dispositions toward STEM disciplines (NSB, 2010). Another notable finding of the Elliot et. al (2001) study was that, though not significant, more students in the interdisciplinary course felt math was important in life. As consistent with reform suggestions that improved interest in STEM topics could lead to greater entry into STEM majors and careers (NAS, 2014; NSB, 2010), Elliot et al., (2001) suggest students in integrated courses may come to believe math is ‘useful, important and even interesting’ (p.815) and that this interest may play an important role in decisions to take additional math courses.

STEM and student attitudes toward learning. This leads into another challenge to the field of STEM education: how to go about achieving that ultimate goal of fostering student interest in STEM subjects not only while in school, but to the extent that U.S. students seek entry into and stay in STEM college programs to actually exit into STEM professions. Modern students do not engage in the world in the same way as past generations, including with their education, suggesting new models of teaching and learning are appropriate (Brown, 2006). Hardy et al., (2008) report a trend among younger generations toward devaluation of subject-specific learning, viewing it as "less important and relevant" (p.215). The nature of integrated STEM learning as active, collaborative, and authentic to the scientific community of practice sets the stage for science learners to develop an identity consistent with that of STEM professionals. This supports the STEM learning goals of developing 21st century habits of mind and creating opportunities for students to develop interest in and motivation to pursue STEM careers.

Integrated STEM Models and Contexts

A consistently emerging theme in discussion of integrated STEM, as evident from the attempt at defining such an abstruse concept, is consideration of the various contexts in which STEM education occurs: Again we must visit the question, what is being taught, when, and how? Relative to teaching other disciplines, integrated STEM poses additional complexity. Fundamental examples of this complexity are evident in questions centered on how many disciplines must be taught, which disciplines must be taught, and how must content be situated relative to other content within a teaching format to meet the definition of integrated STEM. The definition proposed within this work allows for flexibility in this interpretation arguing instead that the context is more important than rigid attention to inclusion of four disciplinary areas at a given time. Indeed, a primary concern in K-12 education is that students participating in STEM programs receive sufficient content-specific instruction to meet national, state, and district achievement goals (Johnson, 2013; NAS, 2014). The emphasis on science and mathematics that seems prevalent in STEM education (Bybee, 2012; NAS, 2014) likely reflects inclusion of these subjects in international tests such as PISA (OECD, 2014) and TIMSS (NSES, 2014). Often technology and engineering are introduced secondarily and though pushes for standardization of technology and especially engineering competencies (IEEE, 2014) have received recent interest, how to include these subjects across grades and disciplines remains problematic.

Resolving the organizational challenges associated with teaching integrated STEM could be at least partially facilitated through use of strong curricula, complemented by rigorous attention to creating a context suitable for integrated STEM learning to occur. In the next section, approaches to integration will be examined beginning with the role of curriculum-based integration in STEM education, followed by a discussion of the importance of context in teaching and learning STEM content and practices.

Curriculum-based integration. Curriculum plays an important role in all education, including integrated STEM education. Curriculum is broadly defined by Merriam-Webster (2013) as “the courses offered by an educational institution”, and more specifically as “a set of courses constituting an area of specialization”. Within education, curriculum is recognized as being much more deserving of both expansion and refinement as evident in the following definition. The Great Schools Partnership’s online Glossary of Education Reform (2014) defines curriculum as typically referring to knowledge and skills students are expected to learn, including learning standards or learning objectives they are expected to meet; the units and lessons that teachers teach; the assignments and projects given to students; the books, materials, videos, presentations, and readings used in a course; and the tests, assessments, and other methods used to evaluate student learning. Researchers define curriculum as what students have an opportunity to learn in school relative to inclusion of particular topics as consistent with sources, enactment, politics, social forces, regulations, sociology of knowledge, and development of materials as occurs through planning, accessibility, and underlying values (McCutcheon, 1982).

This definition is much more consistent with what teachers mentally invoke when they hear the term "curriculum" and as a result, in the area of integrated STEM education which has newly emerged on the educational playing field, available curricula would be viewed as sparse, as will be revealed in the qualitative discussion section of this paper. Thinking back to previous efforts to define integrated STEM, it becomes immediately obvious that finding curricular resources appropriate for integrated STEM instruction could be troublesome. Furthermore, integrated STEM education requires curriculum integration of its own (Wang et al., 2010) which requires an entirely unique approach to identification and acquisition of curricular resources.

Citing work from Beane (1997) Wang et al., (2010) describe major aspects of curriculum integration, which are summarized herein: Curriculum integration connects disciplinary knowledge with personal and real-world experiences. Four primary aspects of curriculum integration include (1) integration of experience, meaning-making from past and new experience, (2) social integration, which requires collaboration and sharing to make learning both accessible and meaningful, (3) integration of knowledge which accepts knowledge as being constructed by individuals negotiating their own life experiences, and (4) integration as a curriculum design meaning curricula should be logically organized around societally important problems and issues (p.3).

Integrated STEM attempts to establish a connection between real-world learning rather than piece-meal presentation of content requiring later reformulation into meaningful knowledge (Tsupros, Kohler, & Hallinen, 2009). Supporting curricula play an important role in achieving the goals of integrated STEM education since the quality of curriculum determines how well common learning in interdisciplinary skills and concepts can be organized into meaningful forms (ASCD, 2014).

Addressing concern that national, state, and district standards may not be met in STEM curricula (Johnson, 2012; NAS, 2013), providing access to appropriate curricula is crucial. To date, little is known about how to ensure curricula support integration in a manner sufficient to support learning while ensuring integrated disciplines receive adequate attention (NAS, 2013). Bybee (2010) proposes a solution: model STEM units organized around major topics and emphasize competencies as learning outcomes to increase support for integrated STEM teaching among all stakeholders. Such an organization is consistent with NGSS which similarly recommends learning centered on major topics and themes. Furthermore, increased emphasis in NGSS on including engineering and technology competencies supports development of integrated STEM curricula (Achieve, Inc., 2013).

Curricula seem to be variably available based upon subject areas and grade levels . One of the most well-known sources for STEM curricula has been *Project Lead the Way* which is an organization providing K-12 curricula and professional development to teachers (PLTW, 2014). Curriculum development has been recognized as important to expanding STEM programs into public schools (NAS, 2013) and the NAS has proposed a national panel be created to collect, evaluate, and develop K-12 curricula similar to that of Project Lead the Way (Kuenzi, 2008, p.28).

Context-based integration. Because learning, regardless of curricular strength and organization, cannot occur independent of context (Pintrich, 2003), it is important to include discussion of context-based integration to provide a more holistic view of considerations for teachers as they attempt to negotiate integrated STEM teaching and learning. Context generally refers to the conditions surrounding a happening or event (Merriam-Webster, 2014). In the education community there are various types of contexts that must be considered before parsing the phrase "context integration" since understanding context in general precludes such specialized reference.

As mentioned, context refers to surrounding conditions around an event. In education, it is appropriate to view a multitude of contexts for learning, including the fact that knowledge is actively constructed by a learner rather than being passively received from the environment (von Glasersfeld, 1987) but also that individuals do not exist independent from their environments and the social influences around them (Vygotsky, 1978). Individual learners do not exist in isolation, indeed school is a place where a single learner is surrounded by fellow learners and a teacher who provide a social context in which learning will occur. Furthermore, an individual learner will be influenced by their own culture and home influences which, combined with the school environment, creates a richly complex, socio-cultural context in which learning happens (Jaworkski, 2014). Certainly it is well established that common constructivist frameworks center on social constructivism as a paradigm since knowledge tends to be socially constructed relevant to context (Bandura, 1971; Bruner, 1991, 1996e; Vygotsky, 1978).

Contextual models. How students differentially respond to teaching and learning contexts suggests it prudent to consider common contextual models in which integrated STEM education occurs. A review of literature elicits that STEM integration can take place in the context of problem-based learning, design-based learning, inquiry-based learning, within formal school environments (traditional classrooms) or informal learning environments (museums, discovery centers, etc.,) or any combination of these. In the next section these learning contexts are explored and evaluated in terms of their potential as productive contexts in which integrated STEM teaching and learning can occur.

Integrated STEM in problem-based learning contexts. Problem-based learning (PBL) is an "instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (Savery, 2006, p. 9). PBL provides students with authentic (Hung, Jonassan, & Liu, 2008; Savery, 2006), often open-ended problems in collaborative settings (Savery, 2006). Consistent with real-world problems, Savery (2006, p. 13) indicates that PBL requires ill-structured problems since learners tend to be more motivated and invested in development of a solution than with well-structured problems. Additionally, Savery (2006) notes that PBL should be integrated from across subjects in similar approximation to how individuals would access information and resources from subject areas in their daily work. Attention to authenticity supported by PBL is strongly aligned with integrated STEM goals as previously described. PBL has been identified for use specifically within integrated STEM settings because of its goal and intent of providing students with opportunities to acquire knowledge and skills through design (Fortus, Krajcikb, Dershimerb, Marx, & Mamlol-Naamand, 2005) and inquiry of topics as presented through STEM disciplines (Satchwell & Loepp, 2002). PBL emphasizes an approach to learning grounded in exploration of solutions to real-world, authentic problems (Laboy-Rush, 2014).

Benefits of problem-based learning as a context for integrated STEM. Positive effects of PBL on integrated STEM learning are evident in a study by Lou, Shih, Diez, & Tseng (2008) of female high school students participating in a solar electric trolley contest. Students using PBL strategies showed improved attitudes toward STEM learning, positive dispositions toward future STEM careers, successful completion of content goals, greater understanding of the meaning of integrated STEM knowledge, active application and appropriation of engineering and science knowledge, and increased exposure to knowledge integration and its applications. Resulting from of the study were recommendation to include more curriculum with PBL strategies.

Problem-based learning has been viewed as a means of scaffolding students into more complex design-based challenges (Barron, Schwartz, Vye, Moore, Petrosino, Zech & Bransford, 1998). Student participation in problem-based work prior to work on design was successful for middle school students designing a business plan for a carnival school booth (Moore, Sherwood, Bateman, Bransford,& Goldman, 1996). Students in the experimental group spent three, one-hour class periods in planning based upon a similar scenario which was read and discussed. In reading the final business plans developed by students, judges who did not know which plans came from experimental versus control groups found plans written by the problem-based learning group to be much higher quality than for students in the design-only group. Successful integration of mathematics principles by the problem-based learning group is especially noteworthy from a STEM integration perspective and warrant weighty consideration of the claims that problem- and design-based learning be used in tandem (Schwartz et al., 1998).

Problem-based learning has been most used to promote learning goals of math and science while design-based learning tends towards engineering applications (Berland, 2013). PBL challenges require solution through application of newly gained knowledge but stop short of requiring design (Berland, 2013). A complementary approach utilizing both design- and problem-based approaches can be hypothesized as a useful approach for integrated STEM. PBL from a design-based perspective will now be explored.

Integrated STEM in design-based learning contexts. Design-based learning is rapidly gaining ground in integrated STEM education (Berland, 2013), especially as technology and engineering gain prominence as disciplinary objectives for long-term student learning (Achieve, Inc., 2013). Described as emphasizing creative and applied learning (Lee & Breitenberg, 2014), design-based learning is learning in which "students work co-operatively and actively on multidisciplinary design tasks with the purpose of gaining qualifications as creative professionals capable of integrating all relevant aspects of education" (Wijnen, 2000). Characteristics of design-based learning include integrative, transdisciplinary, practice-oriented (Wijnen, 2000), creativity and collaborative abilities (Lee & Breitenberg, 2014). Consistent with STEM integration objectives, much emphasis in design-based learning rests upon authenticity (Strobel, Wang, Weber, & Dyehouse, 2013).

Currently, much design-based learning targets easily approached learning goals such as understanding machines in the physical sciences or providing a specific solution to a human problem as in engineering (Achieve, Inc., 2013). Increasingly design challenges such as how to deliver medications to specific locations in the human body, how to neutralize a virus, or how to safely remove natural resources from the earth provide opportunities for students to address real world problems in a context consistent with the actual problems facing humanity. Design is not limited to the Rube-Goldberg project or examination of trajectories.

A study by Berland (2013) examined STEM integration from a design-based perspective. The curricular materials developed for the study situated all student work as occurring within the context of STEM-design challenges and had a goal of student appropriation of engineering competencies while ensuring math and science content were taught. The unit required that students design and build a pinhole camera capable of taking a picture of a specific object. The researchers note, from prior experience (Berland & Busch, 2012) the importance of explicitly discussing and emphasizing math and science concepts since, though inherently forming the foundation for principles underlying the development of the camera, they are not necessary to successful design of the camera. Subsequently, need for explicit attention in design-based activities to disciplinary principles should be considered in STEM integration.

Concern about learning math and science content while participating in design-based activities is preceded in research by Petrosino (1998 in Schwartz et al., 1998) on middle-school students participating in a model-rocket activity. It was found students learned little about the scientific or mathematical principles guiding rocket science when they simply participated in the act of designing and launching a rocket. Encouragingly, the research did demonstrate that providing students with a driving question, in his case attention to scientific method, demonstrated that students could appropriate both goals of design and learn the role of science in that design. Importantly, the research showed that students *can* use their attention to scientific knowledge to direct their learning, though attention to assessment was again not included. Assessment will specifically be discussed in the discussion section of this research document.

Other challenges to STEM integration in the design-based unit studied by Berland (2013) include the finding that using engineering problems to teach science could be problematic given reliance of student connection-making between design work and science conceptual understanding on teacher pedagogical approach and classroom culture (p. 30). Additionally, the possibility of conflict between engineering habits of mind and scientific habits of mind can create discord for students. Finally, the engineering context limited the math and science concepts that could be taught due to the need to align math and science with design goals. The author conceded that the study was not constrained in selection of math and science concepts for use by a list of standards (p.31): an unusual case raising an important concern about ability to integrate design-based learning into daily classroom activity even when the goal is STEM integration.

Integrated STEM in inquiry-based learning contexts. Another type of learning context in which STEM integration takes place is inquiry-based learning. Inquiry-based learning occurs when students naturally become engaged and participatory learners through exposure to problems or tasks that lend themselves to curiosity and motivation to explore (Fogarty, 1991). Learning occurs as students process information in these settings (Oliver, 2008). Student-generated questions and interest lead to different outcomes to inquiry learning (Wallace, Tsoi, Calkin, & Darley, 2003; Tabak & Reiser, 1997). NSES (1996) define inquiry as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p.23)

Student-generated questions have been viewed as powerful motivation for learning. However, it has become evident that teacher facilitation of learning through discussion and formal questioning may be required to ensure students meet learning goals as demonstrated in an inquiry-based learning study by Tabak & Reiser (1997). A study of high-school students in an inquiry unit found science learning was enhanced when student collaboration was accompanied by three supports: (1) domain-specific strategic supports which focused investigations and discussions on the topic at hand, (2) teacher-student discussion during small-group sessions which scaffolded computer-based learning, and (3) teacher facilitation of discussion during whole-group sessions which allowed for class reflection and shared-experiential learning. Given the open-ended nature of many integrated STEM problems, which may be inquiry-based, attention to the need for teacher facilitation and scaffolding is warranted. It has been established that knowledge, experiences, and background of teachers plays an important role in integrated STEM teaching and learning efficacy, but that more research is crucial to further understanding the nature of this relationship (Stohlmann, Moore, & Roehrig, 2012). This paper has a primary goal of establishing an effective measure of these constructs.

Disciplinary overlap. As the previous sections suggest, each STEM discipline has its own set of priorities in terms of teaching, learning, outcomes, goals, and orientation to reform. Some of these can be viewed as singular goals, or modalities. However, as is evident in the recently released Next Generation Science Standards (NGSS), there are many common goals across disciplinary areas that support integration (Table 1). These modalities of overlap provide strong tools for curricular development when planning science lessons as the center of an integrated STEM curriculum. Indeed, it could be argued that all of these modalities actually belong in a single cell when one takes that perspective that science informs technology and engineering and that mathematics is the descriptive power of much science and engineering, and that technology is a powerful tool for navigating and advancing science, engineering, and mathematics.

In the NGSS are found science and engineering practices Table 1, and most of the items actually do overlap, such as developing and using models, which though not expressly mentioned in standards, could easily be applied to mathematics. For science, asking questions is emphasized over the engineering goal of defining problems, and constructing explanations as a scientific practice is replaced by designing solutions in engineering (NGSS, 2013, Appendix F, p. 1).

Table 1: *Standards as Modalities*

STEM Focus	Science A	Technology B	Engineering C	Mathematics D
Science 1	- Asking questions[1,5] - Constructing Explanations[1]	- Creativity and innovation[2] - Research and information fluency[2] - Communication and collaboration[2] - Critical thinking, problem solving and decision making[2]	- Developing and using models[1] - Planning and carrying out investigations[1] - Analyzing and interpreting data[1] - Using mathematics and computational thinking[1] - Creativity and innovation[2] - Communication and collaboration[2] - Critical thinking, problem solving and decision making[2]	- Understand patterns, relations, and functions[4] - Use mathematical models to represent and understand quantitative relationships[4] - Analyze change in various contexts[4] - Develop and evaluate predictions that are based on data[4] - Understand and apply basic concepts of probability[4]
Technolog y 2	Same as B1	- Digital citizenship[2] - Technology operations and concepts[2] - Designing Solutions[1]	- Develop an understanding of the attributes of design[3] - Students will develop an understanding of engineering design[3]	- Understand patterns, relations, and functions[4] - Use mathematical models to represent and understand quantitative relationships[4]
Engineerin g 3	- Apply appropriate techniques, tools, and formulas to determine measurements[4]	- Students will develop the abilities to apply the design process[3]	- Defining problems[1] - Designing Solutions[1]	- Specify locations and describe spatial relationships[4]
Mathemati cs 4	- Understand measurable attributes of objects and the units, systems, and processes of measurement[4] - Apply appropriate techniques, tools, and formulas to determine measurements[4] Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them[4] - Select and use appropriate statistical methods to analyze data[4]	Same as B2	- Problem solving[3] - Analyze characteristics and properties of two and three dimensional geometric shapes[4] - Apply transformation and use symmetry to analyze mathematical situations[4] - Use visualization, spatial reasoning, and geometric modeling to solve problems4 - Understand patterns, relations, and functions[4]	- Understand numbers[4] - Understand meanings of operations[4] - Compute fluently[4] - Represent and analyze mathematical situation and structures using algebraic symbols

[1]Next Generation Science Standards (2013), [2]International Society for Technology in Education (2007), [3]International Technology Education Association (2000), [4]National Council of Teachers of Mathematics (2015), [5]Repetion indicates a standard fits into multiple modalities

The NRC (2012, p. 210) discusses the interconnected nature of not only science and engineering, but also of technology as evident in the statement, “Together, advances in science, engineering, and technology can have…profound effects on human society, in such areas as agriculture, transportation, health care, and communication, and on the natural environment.”

Overlap in technology and science standards can be seen in such standards as those from the International Society for Technology in Education (ISTE) supporting student development of “creativity and innovation”, “research and information fluency”, “communication and collaboration”, and “critical thinking, problem-solving, and decision making” (2007). These can also be easily viewed as in kind goals of engineering which is a discipline that values innovation, collaboration, critical thinking, problem-solving, and decision making as characteristics of professionals in that career field. Similarly mathematics would likely also value these objectives for student learning, but specifically, mathematics requires creative solutions to problems, critical thinking, problem-solving, and decision making.

Integrated STEM in formal v. informal contexts. The context in which integrated STEM education occurs must also include discussion of where learning takes place, be this a formal education setting such as a traditional classroom or an informal setting such as might be offered by museums, science centers, or after-school programs. Concerns about meeting achievement goals and testing benchmarks originally led many schools to offer informal, STEM-enhanced opportunities though there is beginning to be a definite trend toward including integrated STEM in everyday, traditional settings (Johnson, 2013). Despite an increasing presence of integrated STEM in traditional settings, a sense of direction for curriculum is lacking. National Engineering Standards were published in 2013 (Carr, Lynch, & Strobel, 2012) but there has not yet been widespread adoption by schools, rather most engineering education occurs in extra-curricular or non-school based programs. A similar situation exists for technology education with its supporting International Standards for Technology Education [ISTE] (ISTE, 2012) which also has not experienced widespread adoption. For this reason, the context in which technology and engineering are taught is variable. The consistent theme prevalent throughout the formal versus informal dichotomy is the fact that integration of STEM subjects is difficult given national, state, and local mandates to include specific content standards, which tends to limit attention to subjects such as engineering and technology which are largely absent in academic requirements and which also have limited curricular availability. Identification of those factors necessary to facilitate fidelity to integrated STEM goals and objectives should be of utmost consideration given the federal expenditure and attention to integrated STEM teaching and learning. Additionally, the move to include integrated STEM education in content areas serves as a reminder that teachers must have confidence, or at least willingness to attempt integrated STEM teaching based on confidence in general content knowledge and pedagogy itself, in order to achieve broader goals, further supporting the research goals of this dissertation.

This chapter establishes a framework for why teaching science in an integrated STEM framework is perceived as a valuable educational objective in the current educational environment. However, as was mentioned just above, teachers play an important role in ensuring that broader educational initiatives are actually implemented in the classroom. In the next chapter the role of the teacher, focusing on the crucial aspect of teacher perceptions of confidence in teaching science within an integrated STEM framework are discussed and relevant literature reviewed.

CHAPTER II - THE ROLE OF THE STEM SCIENCE TEACHER

Key Challenges in STEM Education

As discussed in the previous chapter, there are several key challenges facing the field of STEM education. Beyond establishing a solid definition for integrated STEM, which is essential to establishing a baseline for research and funding, it is necessary to understand how integrated STEM should be taught. First and foremost in confronting STEM teaching is the lack of a clear understanding of how to effectively teach STEM subjects in a manner most beneficial to achieving desired STEM outcomes. How STEM careers are actually manifest in the workplace can be quite different from how STEM is taught in schools (Morrison, 2006; Morrison & Bartlett, 2009). In STEM careers, science, technology, engineering and mathematics are thoroughly integrated and not perceived as separate disciplines: rather each discipline represents a tool for achieving the work of the other disciplines (Morrison, 2006). In education, science, technology, engineering, and mathematics have historically been treated as individual disciplinary areas and taught in schools as distinct subject areas, and some simple approaches still view teaching and learning as consistent with STEM so long as each of the four disciplines is a core focus – even if they occur in isolation (Johnson, 2012). In yet another approach, some attempts at STEM have the goal of using two or three of the STEM focus disciplines to support teaching content and curricular goals of the other disciplines, as with technology, engineering, and mathematics being included to support the overarching goal of teaching science, or engineering and technology supporting science and mathematics (Williams, 2011). If learning is to occur within an integrated STEM framework some semblance of understanding through a consolidated definition of integrated STEM and some best practices for facilitating integrated STEM must be developed. Additionally, a greater understanding of the supports and knowledge teachers must possess relative to their confidence about these abilities (self-efficacy) must be further explored.

Another example of problems arising from the current model of disciplinary-centered teaching and learning is evident in Rose (2007), who, in a descriptive study of STEM stakeholders' knowledge of technological literacy and the goals of technological literacy found variable approaches and understandings about the role of technology based upon disciplinary field, with equally variable valuation of aspects of technology as a tool or as an outcome of another discipline. Disciplines also differently valued technological literacy as a goal of STEM education. Science educators tended to most highly prioritize science literacy, but the study author points out the emphasis of technology present within science literacy guidelines (AAAS, 1993) and content standards (NRC, 1996). Notably, science community values were different from those of the engineering community who tended to value technological literacy in terms of knowledge and abilities enabling job performance. This was a different approach still to technological literacy from the mathematics community who valued technology for providing tools to enable abilities and knowledge to teach, learn, and do math with the purpose of solving problems. Accordingly, those in technology view the role of technological literacy in STEM education differently from each of the other three focal areas. Study outcomes supported the argument that a *common* understanding of disciplinary literacy among STEM stakeholders is potentially a necessary condition for implementation of successful curricular programs (Rose, 2007).

What remains unresolved, since Rose (2007) was writing from a technology perspective, is the role technology *should* play in STEM education, and accordingly, what *should* be the role of each of the four disciplines relative to each other in STEM education if students are to have the desired outcomes of being engaged with STEM content and learning to the extent that it increased immediate classroom goals and long-term goals for student graduation from STEM programs and subsequent entry into STEM careers. STEM goals may be partially facilitated since STEM education is reported to increase problem-solving skills, critical thinking, analytical thinking by students and fosters real-world connections to curriculum (Brown, Brown, Reardon, and Merrill, 2001; NSB, 2007), yet again, with these goals in mind, there is no clear explanation of the content and context in which STEM must be taught for this to occur.

Furthermore, STEM subjects have different contextually-based epistemologies; problematic considering individual teachers tend to be very discipline-focused (Williams, 2011). This can result in a fragmented approach to inclusiveness of all four STEM disciplines and a tendency toward emphasis on a single subject (Sanders, 2009). Even in cases where teachers do attempt to teach all STEM topics, uncertainty related to how well teachers actually understand each of the four major disciplinary areas of STEM outside of a specialty area is of significant concern (Rose, 2007). Approach or orientation to teaching each discipline can also vary based upon the disciplinary and sub-disciplinary background of the teacher causing variation in how content is taught, the depth of content taught, the domain-specific practices convered, as noted by Ball, Thames, and Phelps (2008), who further support this premise with the statement that biology-trained teachers will teach physics differently than chemistry or physics teachers (p. 393). This within-discipline disparity further supports concern for how well teachers will be able to teach across STEM topics. Given that research suggests teacher quality is an important factor affecting student learning (CITE) and the lack of a framework for helping teachers develop STEM related pedagogical knowledge (CITE), a discussion of literature related to teachers' attitudes, knowledge and skills related to integrated STEM merits discussion. The following section is devoted to a discussion highlighting the importance of teachers' knowledge and skills related to STEM integration.

Teachers and their Role in STEM Integration

Few would argue against teachers playing a central role in how teaching and learning unfold in the STEM classroom. Teacher attitudes, beliefs, knowledge of content and pedagogy, experience, and many other attributes can be used to explain both teaching and learning outcomes to some extent across various disciplines (Shulman, 1986). Yet little research has explicitly focused upon teacher orientations towards and pedagogical knowledge of integrated STEM education: a shortcoming given the emphasis on integrated STEM and STEM funding as previously discussed in this paper. Subsequent discussion will include examination of the role of factors such as teachers' attitudes, pedagogical and subject matter knowledge in STEM disciplines, knowledge of authentic practices in STEM, and teacher conceptualization of integrated STEM teaching and learning. All of these topics will be considered relative to teacher attitudes and beliefs about integrated STEM teaching and learning with emphasis on the importance of teacher self-efficacy which will be argued as playing a central role in teaching and learning outcomes in integrated STEM classrooms. Discussion of teacher knowledge of content and pedagogy in general, knowledge of content a and pedagogy for teaching integrated STEM, and teacher attributes such as attitudes, experience, and orientation to teaching follow in the next section of the paper.

Knowledge of content and pedagogy. A daunting challenge in integrated STEM education is teacher education and professional development sufficient to prepare teachers for teaching in an integrated framework (NSB, 2010). In the absence of foundational preparation even with available resources, teachers may simply not know how to integrate subjects effectively (Furner & Kumar, 2007). This is troublesome considering successful learning within STEM frameworks requires teachers able to guide and facilitate learning concurrent with, and dedicated to those learning goals (Stohlmann, et al., 2012). This necessitates a skilled group of educators knowledgeable in the domain-specific content, practices and pedagogies of integrated STEM teaching and learning. This is important because quality of education depends upon actions of teachers in the classroom which are informed by what the teachers know about content, practices and pedagogies related to each STEM (Furner & Kumar, 2007).

As a relatively new subject requiring innovative practices, schools and teachers dedicated to attempting to implement integrated STEM teaching and learning may still face pedagogy and content challenges from demands of integrated teaching, which can be predicted to have an effect on associated teacher attitudes and beliefs. A study by Stohlmann et al. (2012) uncovered several areas of concern for teachers teaching in an integrated STEM. First, due to the student-centered format of integrated STEM teaching in which students develop their own ideas teachers found it difficult to predict what direction students would take their studies. Also problematic is provision of ample materials and resources necessary to allow students to design, test, and revise solutions to problems (Stohlmann et al., 2012, p. 30). Even given adequate curricula and materials, teachers must still possess the pedagogical knowledge necessary to teach integrated STEM, which leads to a major research focal point for this study: Relative to what a teacher must know and be able to do in order to teach effectively in any setting, what differences exist for pedagogical knowledge required for teaching in integrated STEM framework, and how do experience, attitudes, and orientation to teaching affect this?

Pedagogical knowledge for teaching integrated STEM. Existing literature supports the hypothesis that a discrete set of pedagogical knowledge for teaching integrated STEM greatly influences teaching and learning outcomes in an integrated STEM program (Grossman, 1990; Magnusson, Krajcik & Borko, 1999; Park & Oliver, 2008; Shulman, 1986, 1987). Because each teacher may be trained, familiar, and skilled in pedagogies related to the domain of their certification, they may not effective teachers in an integrated STEM teaching context. Therefore, a discussion around teachers' pedagogical knowledge in the context of integrated STEM deserves attention.

Pedagogical knowledge is a general type of knowledge including broad practices such as classroom management and curricular organization (Shulman, 1987). Many of the general pedagogical constructs can be traced to Bruner (1996) who elaborates upon the role of teachers in understanding childrens' minds, children as learners, and children as autonomous managers of knowledge and thinking. In other words, teachers must understand students if they are to facilitate student learning. These ideas can be traced back even further to Dewey (1902) who recognized the importance of delivery of knowledge sensitive to the needs of students with attention also to relevance through attention to prior knowledge. Dewey (1987) was one of the first proponents of the image of teachers as a *facilitator* rather than a *deliverer* of knowledge, stressing student-teacher relationships as a partnership rather than a give-and-take from a larger bank of knowledge. Dewey's (1916, 1925) theories of education and education reform including attention to the social aspects of learning and the processes in which this type of learning can occur greatly set the stage for later education reform.

How teachers learn the knowledge and skills necessary to become practitioners of teaching begins in pre-service, institutional education programs which vary in their attention to subject matter knowledge and pedagogical knowledge. Teachers emerge from these programs with correspondingly variable degrees of confidence and ability in each of these knowledge bases which they must then apply to the context in which they find themselves employed.

The idea that content and pedagogy are central to effective teaching retrospective to Shulman's (1986, 1987) explanations, seems an acceptable description of the types of knowledge teachers must possess to accomplish the work of teaching through integrated STEM. What was not explained through content and pedagogy alone however, was how content must be transformed through pedagogical practices and that these practices changed depending upon the content and context of teaching. Integrated STEM as a fairly new discipline is relatively unexplored in terms of teacher pedagogy. Unsurprisingly then, STEM will present its own set of pedagogical constructs and skills for successful teaching and learning to occur.

This research adopts the position that pedagogical knowledge for integrated STEM will vary among teachers from naïve to sophisticated and that this variation will be at least partially associated with level of teacher experience. Further, it is argued that teacher perception of self-efficacy to teach science content in an integrated STEM framework will be heavily tied to beliefs about one's own abilities, or confidence in ability, to meet personal expectations relative to pedagogical knowledge for integrated STEM teaching.

The basis of this argument is grounded in the premise that teaching in an integrated STEM framework is a complex act (NSB, 2010). As with teaching other disciplines, teachers must have both disciplinary and interdisciplinary subject matter (content) knowledge Doering, Veletsianos, Scharber, and Miller, 2009) and general pedagogical knowledge of teaching (Burn, Hagger, Mutton & Everton, 2003) which includes understanding of teaching practices, how students learn, and strategies to promote deep learning. For integrated STEM teaching and learning all of this espoused knowledge must be enacted through STEM career practices such as questioning, modeling, argumentation, and computational thinking (NSB, 2010). Furthermore, to teach content effectively, teachers must have confidence in their ability to facilitate these actions within themselves (intrinsic) or within students (extrinsic).

Duration of experience versus orientation to teaching. Teacher education doesn't stop when teachers enter the workforce: recent research suggests actual practice does more to develop and improve teacher pedagogical knowledge than does instruction about pedagogical knowledge (Justi & vanDriel, 2005; vanDriel, 2010; Windschitl, Thompson, & Braaten, 200). Therefore, experience can play a significant role in learning to successfully teach through an integrated STEM framework.

Though teacher experience supports ability, duration of experience is only one factor of teacher pedagogy, which supports the second part of the argument: that pedagogical knowledge varies from naïve to sophisticated not solely based upon years of experience, but based upon other teacher characteristics such as attitudes, beliefs, and especially beliefs about self-efficacy as is discussed in the theoretical framework, chapter two, of this paper. However, before addressing self-efficacy, it is necessary to briefly visit teacher attitudes and beliefs which are the theoretical foundation of later self-efficacy research, recognizing that self-efficacy is a specific subset of beliefs, being "belief, of confidence in ability to…" Attitudes and beliefs are thus discussed in the following sections.

Teacher Attitudes

Teacher attitudes have been established as central to effective teaching. Teacher attitudes refer to how individuals are oriented toward objects or events and can be positive or negative (de Souza Barros & Elia, 1997, Koballa & Glynn, 2007). Attitudes are classified as affective variables (Shibeci, 1984) meaning variables that are related to feelings with motivation and attitude considered as predominantly important (Bohner & Schwarz, 2014). Attitudes provide information about how an individual orients him or herself toward a teaching moment, and being resistant to change, are cognitively more important to teacher behavior, but less emotionally construed (Philipp, 2007). Fishbein & Ajzen (1975) describe the psychological processes by which individuals orient and act in given circumstances. Attitudes can often be described as antonyms, for example, like versus dislike (Philipp, 2007).

Beyond being affective, attitudes are also cognitive, referring to how individuals orient themselves relative to objects (Aiken, 1980). Additionally, attitudes may be behavioral, suggesting individuals act according to attitudes and objects in discrete ways (Gomez-Chacon, 2000). To date there is a deficit of research studying teacher attitudes towards teaching integrated STEM, yet the importance of teacher attitudes towards teacher behavior suggests this as a fruitful area of research. Therefore, a study that focuses on teachers' self-efficacy to teach science through integrated STEM cannot ignore teachers' attitudes. Still, while attitudes can influence behavior, attitudes alone are insufficient to explain behavior (Kennedy & Kennedy, 1996) and must be considered concomitant to beliefs when making judgments about the potential role of teacher attitudes on integrated STEM teaching and learning outcomes.

Teacher Beliefs

Teacher beliefs are most simply defined as information individuals accept as true (Koballa, 1985, in Fettahlioglu & Ekici, 2011). However, beliefs are viewed by many to be much more complicated (Clandinin & Connelly, 1987; Tatto & Copeland, 2003) and include combinations of descriptive, evaluative, and prescriptive orientations (Pajares, 1992, p. 314). Teacher beliefs are intrinsically linked to behavior and play a central role in formation of attitudes about teaching and about students and their abilities (Bandura, 1982; Pressley, et al., 2003). Beliefs influence behaviors in terms of outcome expectations and beliefs about personal ability (Bandura, 1977; Bayraktar, 2011; Cakiroglu, Cakiroglu, & Boone, 2005). For teachers, beliefs influence perceptions and judgments which subsequently influence behaviors in the classroom (Pajares, 1992). Beliefs have been suggested to be one of the most powerful constructs for consideration in planning teacher education (Pintrich, 1990) and should be distinguished from teacher knowledge since “knowledge of a domain differs from feelings about a domain” (Gess-Newsom, 1999; Pajares, 1992, p.309). Teachers may place more emphasis on beliefs than knowledge when making teaching decisions (Wallace & Kang, 2004) .

When considering teacher beliefs it is essential to distinguish interactions of a wide range of beliefs that influence teaching behaviors. Teacher beliefs include beliefs about the goals and purposes of education (VanDriel, Bulte, & Verloop, 2007), beliefs about teaching and learning, and beliefs about students (Bayraktar, 2011) including their roles, abilities, and responsibilities (Pressley et al., 2003). Teacher beliefs are also discipline-centered (Bandura, 1977) and, in science education, include beliefs about the nature of science and science content (Fonseca, Costa, Lencastre, & Tavares, 2012), and the purpose of teaching science itself (Van Driel et al, 2007). Discipline-centered beliefs also include beliefs relating to personal ability to teach science (Bayraktar, 2007), how science is taught, and beliefs about what is important for students to know about science (Van Driel et al., 2007).

Teacher beliefs should be considered in concert with teacher attitudes when describing orientation to teaching as well as when making judgments about enacted behaviors in the classroom. Riggs & Enochs (1989), provide an example intended to elucidate the relationship between attitudes, beliefs, and behavior by describing a science teacher judging him or herself to be lacking in ability to teach science as a *belief* that then leads to a dislike for teaching science, which is an *attitude*. The outcome is a teacher who avoids teaching science which is categorized as a *behavior* (p.4). Therefore, both teachers' beliefs and attitudes must be taken into account as they play a critical role in teachers' approach to teaching a specific domain, in this case integrated STEM.

After discussing and elaborating on teachers' knowledge, beliefs, and attitudes for teaching integrated STEM, the following discussion explores the theoretical framework guiding the direction of inquiry, namely social cognitive theory and self-efficacy.

CHAPTER III - METHODOLOGY

Theoretical Framework

Social Cognitive Theory

The theoretical framework guiding this study is social cognitive theory. Social cognitive theory is a psychological and sociological perspective defined by Bandura (1986, 2002) as a triadic reciprocal causation model wherein three factors, (1) cognitive, affective and biological events, (2) behavioral patterns, and (3) environmental events all interact as bidirectional determinants of behavior. In this model, humans exist within environmental structures that can be categorized as imposed, selected, or constructed environments consistent with amount of control an individual has over existence in their environment (Bandura, 2002). Social cognitive theory provides an explanation for how and why individuals behave as they do. To understand social cognitive theory it is necessary to examine the theoretical frameworks from which it emerged.

Social cognitive theory finds its roots in behaviorism (Pavlov, 1897; Skinner, 1948, 1971; Watson, 1913). Behaviorism understandably provides the foundation for research focused upon observable behaviors, as opposed to inferred mental processes. Behaviorism adheres to the notion of stimulus-response predictability, or classical conditioning as explained by Pavlov (1897) in the famous “Pavlov’s dogs” studies. Pavlov found that salivation could be predicted by exposing a dog to a specific stimulus associated with food; in other words, the dog was being conditioned to react in a certain way when exposed to a consistent, associated stimulus. Stimuli-response associations also provided the foundation for behaviorist B.F. Skinner (1936, 1948, 1971) to expand behaviorism as a societal mechanism.

Behaviorism waned in popularity during the 1970's and 80's with the emergence of Vygotsky's (1978) cognitivism with its socio-cultural underpinnings as a primary explanatory factor for human behavior (Pressley, 2003) and cognitive constructivism as described by Bruner (1966, 1973) to be instruction in which the student must have experience and contexts that create a learning environment in which knowledge naturally is acquired through a structure in which learning occurs as students fill in the gaps between previous knowledge and experiences. Vygotsky assumed a social-constructionist approach to understanding how people learn and how they learn to behave in society: an approach that remains at the core of existing educational philosophies. Vygotsky played a role in modern cognitive psychology as the primary motivator of belief in the social mind over the individual mind (Segall & Maxwell, 2003) as established by Piaget (1952; 1969).

From Vygotsky's (1978) social-constructionist theories arose social learning theory (Bandura, 1969, 1977) which describes behavior as being learned through observation of others and of self relative to others as opposed to behaviorism which is rooted in responsiveness. Social learning theory views humans as information processors in a socio-culturally situated environment (Reynolds & Miller, 2003). Despite his role in the establishment of sociocultural theory, Bandura (1986) shortly thereafter allowed research suggesting information processing is a cognitive action to direct the emergence of a new theoretical framework. This framework, social cognitive theory, provides a basis for understanding how humans navigate a socioculturally influenced environment in the face of dynamic interactions between the individual (person), their environment, and their behaviors: reciprocal interactions that require a cognitive explanation.

Social cognitive theory views individuals as "agentic operators" (Bandura, 1999, p. 22) though agency is an interactive endeavor since behavior cannot be viewed independent from external influence (Bandura, 1986, 1997). There are three modes of agency: personal agency which is exercised individually, proxy agency in which outcomes are achieved by influences from others to act of one's own behalf, and collective agency in which groups of individuals act together to achieve common goals (Bandura, 2002; Goddard, Hoy & Hoy, 2000). Social cognitive theory is one of five theoretical perspectives explaining individual agency which is defined in educational settings as self-regulation of learning and social goals (Shunk, 2014).

Agency is a cognitive factor and Bandura (2001, p.3) notes the importance of cognitive factors as predictors of behavior because they explain how individuals navigate challenges and make decisions in the face of sociostructural influences. Behavior stems from forethought which guides agency (Bandura, 1991). Furthermore, Bandura (2001) emphasizes agency as intentionality and distinguishes intentionality from action and outcome. Intentionality involves the choice to enact or not to enact a behavior. Intentions affect the likelihood of course of action, while outcomes are consequences of agentic actions (p.6).

Social cognitive theory can be used to explain teacher attitudes and beliefs and subsequently teacher behaviors in the classroom given understanding that underlying causal structure explains development of competencies and regulation of action (Bandura, 1986). Bandura (2002, p.26) describes conditions that control adoption of behavior which include self-efficacy, possession of adequate resources, outcome expectations, and perceived opportunities and impediments. Teachers, as viewed through the lens of social cognitive theory will set goals and plan courses of action that produce desired outcomes and avoid detrimental outcomes (p.27). For integrated STEM education, understanding teacher decision making given probability outcomes relative to internal beliefs in capability can potentially provide a valuable guidance for development of integrated STEM educators.

Self-Efficacy Theory

Teacher beliefs include an important construct of social cognitive theory known as *self-efficacy theory* (Bandura, 1997, 2002); Barros, Laburu, & DaSilva, 2010). Self-efficacy is defined as belief in one's ability to successfully accomplish a task under specific conditions (Bandura, 1977, 1997). Self-efficacy differs from prior locus of control theory (Rotter, 1966) which alternatively positions outcomes as being determined by internally generated actions of the individual or by external factors outside of the individual's control. Bandura (1997) proposes a theoretical framework for self-efficacy as emergent from and central to social cognitive theory (Pajares, 1992). Self-efficacy theory is described as the "foundation of human agency" since belief in ability to produce desired effects is necessary for action and perseverance in the face of challenge (Bandura, 2002, p.27). This theory suggests that an individual's expectations about his or her abilities to perform an action/task such as teaching will influence coping behaviors and both amount and duration of effort put into an action/ task in the face of challenges. Further emphasized is the role of four specific factors in establishment of personal expectations of ability as arising from various influences including mastery experience, vicarious experience, verbal persuasion, and physiological states (Bandura, 1997, 1994, 1997; Pajares, 2002).

Mastery experiences are considered to be the most important factor influencing personal expectations. Mastery experiences are effective performance experiences capable of producing psychological change. Mastery experiences influence initiation and persistence of coping behavior (Bandura, 1977), and boost self-efficacy because individuals are more likely to attempt something new if they have had a similar successful experience in the past (Bandura, 1994). In education, mastery experiences have been defined as sense of satisfaction with past teaching success (Tschannen-Moran & Hoy, 2007) and arise from teaching accomplishments with students (Bandura, 1997). Self-efficacy beliefs will be higher for teachers viewing their performance as successful and lower for teachers who view their performance as a failure, in which case they subsequently predict failure for future similar performances (Tshannen-Moran & Hoy, 2007).

Vicarious experiences occur when an individual observes behaviors being modeled by someone else, but about which the observer develops beliefs regarding ability to successfully appropriate that set of behaviors (Bandura, 1997). When modeled behavior occurs outside of the observer's perceptions of ability on factors such as race, gender, experience, or other characteristics which the observer feels he or she cannot change, despite the competency of the modeler, the observer will not gain self-efficacy (Tschannen-Moran & Hoy, 2007, p. 945). Similarly, psychological and emotional states such as pleasure or stress will influence teacher feelings of capability (Tshannen-Moran & Hoy, p. 945).

Verbal persuasion relates to the interactional feedback regarding performance and capability as put forth by colleagues and peers (Bandura, 1997; Tschannen-Moran & Hoy, 2007; Tschannen-Moran, Woolfork-Hoy, & Hoy, 2008). Verbal persuasion, whether general or specific, may not be the most important effector of personal expectation since verbal persuasion may stimulate an individual to attempt a task but actual success with student learning may be necessary to change self-perception of teaching competence (Tshannen-Moran, et al., 2008).

Physiological states refer to emotional and physiological arousal within a teaching event and depending on whether the arousal is positive or negative this arousal will likewise positively or negatively influence self-perception of competence (Bandura, 1997; Tshannen-Moran, et al., 2008). Negative physiological states caused by factors such as stress, anxiety, worry, and fear negatively impact self-efficacy and may lead to self-fulfilling prophecies of failure or lack of capability to perform successfully (Pajares, 2002).

Both self-efficacy beliefs and outcome expectations can be combined to predict behavior, but self-efficacy is a better predictor since outcome expectations depend upon judgment of ability to perform in a given situation (Bandura, 1997, p.21). Efficacy beliefs vary based upon strength, or intensity of belief to perform a task, and by level, which is the perceived degree of difficulty of a task and must be considered in the context of generality, which is the degree to which self-efficacy beliefs oriented toward one task my generalize to other similar activities (Dellinger et al., 2007). Self-efficacy is both context and situation specific (Bandura, 1997) as when teachers may feel highly effective in one area of science but not another (Hanson, 2006).

The importance of self-efficacy in teacher decision-making should be emphasized since other theories such as expectancy-value theory (Azjen & Fishbein, 1980; Rotter, 1982) fail to explain why, despite benefits derived from specific actions, individuals may decide not to participate in those actions (Bandura, 2002). Individuals, here teachers, with high self-efficacy will set challenging goals and approach challenges with increased or sustained effort while teachers with low self-efficacy will avoid participating in activities or give up in the middle of an activity if they doubt their abilities or perceive obstacles to success (Bandura, 1994).

In science education, it has been established that self-efficacy and teaching practices are related. Low self-efficacy translates to high science anxiety, poor attitudes toward science, and reluctance to teach science (Ramey-Gassert & Shroyer, 1992). Teachers with low self-efficacy experience high levels of anxiety and poor attitudes toward science teaching, which translates to a decrease in time spent teaching science (Koballa & Crawley, 1985; Lorens et al., 2005). It can be predicted that these trends would apply to other disciplines such as STEM teaching and learning. For the purposes of teaching within an integrated STEM framework, which has been established as a complicated and intellectually challenging endeavor, teacher self-efficacy can be hypothesized to be a significantly important predictor of teacher behavior; both success and failures.

Self-efficacy expectations are belief in one's *ability* to successfully carry out a behavior required to produce an outcome while outcome expectations are based upon belief about whether behaviors *will* produce certain outcomes (Bandura, 1977, p.193).

In terms of integrated STEM instruction, the previous sections established the importance of, first and foremost, belief in ability to teach STEM in an integrated manner since belief in ability determines coping behaviors and amount of effort put into a task in the face of challenges Bandura, 2002). Belief in ability to successfully teach integrated STEM arises from beliefs in ability to appropriate subsidiary constructs making up the set of characteristics defining integrated STEM. Based upon this review beliefs would be influenced by (1) mastery experiences and teaching success, (2) vicarious experiences, (3) positive psychological and emotional states while in the act of teaching and/or planning for teaching, and (4) verbal persuasion in the form of positive reinforcement from peers and other stakeholders. Further, it has been established that teacher understanding of what integrated STEM teaching and learning means could be integral to teacher self-efficacy to teach integrated STEM. Correspondingly, knowledge of integrated STEM teaching and learning as well as subject matter (content) knowledge, pedagogical competency, sense of support, and curriculum availability may all influence integrated STEM teaching and learning through attributes both directly related to those constructs as well as through feelings of self-efficacy relative to those constructs. The primary research objective of this study will be to identify the factors influencing STEM teaching self-efficacy. Those factors will ultimately be the items used in the development of an instrument to measure science teacher self-efficacy to teach integrated STEM.

Methods

Research Goals & Design

The primary research goal of this study was to develop and validate an instrument to measure science teachers' self-efficacy to teach science within an integrated STEM framework. To do this a survey instrument was developed and administered along with interviews of select participants using a mixed methods, sequential, explanatory design (Ivankova, Creswell, & Stick, 2006) targeting active science teachers across K-12 grade levels. A mixed methods approach is defined as collection, analysis, and integration of both quantitative and qualitative data for the purpose of gaining a better understanding of a research problem (Creswell, 2005; Ivankova et al., 2006; Tashakkori & Teddlie, 2003). The use of quantitative and qualitative methods are used when neither alone is sufficient to fully capture trends and details of a study (Ivankova et al., 2006). The mixed-methods, sequential, explanatory design, popular among researchers (Ivankova et al., 2006) is a two-phase design in which first quantitative (1^{st} phase) and then qualitative (2^{nd} phase) data are collected (Creswell, 2003). Quantitative data will be used to identify predictive power of constructs as indicators of self-efficacy to teach science within an integrated STEM framework. Secondarily collected qualitative data from semi-structured interviews will provide further explanatory power to the predictors identified in the quantitative phase (Creswell, 2003).

Methodological issues that must be considered when conducting mixed-methods sequential, explanatory design include (1) assigning priority or weight to the quantitative and qualitative data during both collection and analysis, (2) sequence of data collection and analysis, and (3) stage in the research process when quantitative and qualitative data are connected and results integrated (Morgan, 1998, & Creswell et al., 2003 in Ivankova et al, 2006, p.3). Creswell et al., (2003) discusses handling these issues, and Ivankova et al. (2006) further provide some guidance for addressing these concerns. This research assigned highest priority to quantitative data collected through the survey. Quantitative results were used to guide the qualitative phase of the research, which justified the sequential approach selected. After qualitative data were analyzed results were integrated with quantitative results and final conclusions and recommendations were made.

For this research, a mixed methods approach was chosen in consideration of the particular goals of this research: to develop an instrument to measure science teacher self-efficacy to teach their content within and integrated STEM framework, and to identify the constructs defining this self-efficacy. While a survey alone can certainly help identify attitudes and beliefs it is necessary to perform some post-analysis interviews, especially when developing a new instrument to improve future reliability of the instrument (Colten & Covert, 2007) and to develop a deeper understanding of those constructs eliciting particularly strong or inexplicable responses from participants. It is known that a limitation of surveys is that they limit amount and type of information as well as response choices (Colton & Covert, 2007). While the use of open-ended questions can partially remediate this problem, the use of qualitative, open-ended interviews can supplement and enhance understanding of survey responses (Creswell, 2003).

Instrument Development

An instrument in the form of a self-response survey for measuring science teachers' self-efficacy to teach science within an integrated STEM framework was developed over the course of a year. As consistent with instrument development protocol, the first phase of development consisted of a review of literature to achieve the important goal of identifying constructs for inclusion in the survey (Colton & Covert, 2007; Devellis, 2011). Major categories for constructs identified from the literature suggest integrated STEM teaching and learning outcomes may be at least partially related to (1) context, (2) teacher attitudes, (3) perceived challenges, (4) integrated STEM model (e.g. problem-based, design-based, inquiry, etc.), (5) type of integration (e.g. curriculum v. context, etc.), (6) teacher knowledge, (7) demographic factors such as experience, (8) a teacher beliefs including perception of self-efficacy. As recommended for initial instrument development over 100 items were originally developed (Colton & Covert, 2007), though by the time the instrument was considered finalized for piloting, discussed later, this number was closer to 40 items. Because Bandura's approach to perceived self-efficacy has been adopted as a theoretical framework, Bandura's methodological approaches, specifically language, are adopted as well, as described in subsequent discussion of instrument development.

Items were compiled in a self-response rating format using a 1-4 Likert-Type scale (DeVellis, 2003) in a disagree to agree format (Roberts, Laughlin, & Wedell, 1999), with 1 representing "cannot do at all" and 4 representing "very confident I can do this" on the general portion of the instrument in which teachers are responding to questions about confidence in abilities (self-efficacy) to achieve tasks in the five categories mentioned above. Alternative language resulting in a shift from the more common format of "disagree to agree" was justified by the need to ensure content validity, and Bandura (2006) indicates the importance of wording self-efficacy items in terms of "can do" since self-efficacy involves perception of capability and "can do" represents a judgment of capability (p. 309). Instruments that have used "will do" measure judgment of intent, and so do not accurately measure self-efficacy (Bandura, 2006, p.309).

Based upon Bandura's instruction and standard response format for self-efficacy surveys, Participants were given explicit instructions and an example on how to respond to the scale.

Responses were rated based upon how strongly participants related to a given construct. A forced-choice format was chosen for several reasons including the possibility of respondents failing to exert the cognitive energy to select a valid choice, opting instead to choose a neutral or no-response category (Duchene, 2015; Krosnick, 1999). The rating scale leaves out an option for neutral responses since the goal of this research is to explore primarily attitudes and beliefs which require positive or negative rather than neutral opinions, as should be evident in the declarative statements to which participants must respond (Roberts et al., 1999). Considering that self-efficacy attempts to measure what participants can do at a given moment, the neutral or "don't know" response disallows for an in-the moment assessment of ability. Self-efficacy allows participants to have either no confidence in their ability or some confidence somewhere along the continuum. Adding a neutral or don't know response category creates a questionable measure of how well participants view their ability to perform an action/task since it obfuscates the distinction between doubt in ability and no-response. For example, if "don't know" or "neutral" was added as a response to the item "I am confident in my ability to develop new knowledge and skills necessary to teach within an integrated STEM framework", it would be impossible to distinguish a neutral or "don't know" response from what could be an intended response of "don't know what knowledge and skills are necessary" or "don't understand the question" or "prefer not to respond".

Some items, namely those demographic items with “other” are followed with open-ended response fields intended to elicit further understanding of certain topics of special interest. A single open-ended question was placed as the last question in the survey to allow participants to explain which of the factors affecting self-efficacy to teach integrated STEM they felt most strongly about. Interview questions representative of the major categorical areas identified through the literature review to be important in addressing research goals were developed and included in the semi-structured interviews.

Pilot study. Teijlingen & Hundley (2001) describe pilot testing as a valuable means of identifying potential failures of project or protocols as well as alerting of inappropriate or overly complex instruments and methods. The pilot study with an original 14 demographic items, five open-ended items, and 80 Likert-type survey items on a 0-10 confidence rating scale with 0 being “cannot do at all” and 10 being “very confident that I can do”) was electronically administered to a convenience sample of 24 teachers at a summer, STEM institute in order to allow for identification of potential problems with question comprehension, errors, and to initially test the instrument. The pilot study also included a post-survey qualitative interview in which researchers interview responses were compared to their questionnaire responses to reveal question complexity, inconsistencies in responses, and misunderstanding of question intent. Of the 24 teachers participating in the survey, nine were interviewed for confirmatory analysis. The pilot study led to indications for removal of two demographic items and re-wording of two items.

The first item flagged for removal was the demographic item “In what subjects are you certified?” since there was a second demographic item that asked “In what subjects are you licensed?” The original intent of including both question was that some technical programs allow for certifications rather than licensure. However, this just confused participants, as uncovered in the interview, since all interview participants equated certification and licensure. As a result, this question was flagged for removal. Questions were flagged for removal rather than taken out because the researcher wanted feedback from the expert panel prior to a final decision to remove the question.

The second demographic item flagged for removal was “How would you describe your school”, with the possible responses “rural”, “suburban”, “urban”, “low diversity”, “moderate diversity”, “high diversity”, “low SES”, “Average SES”, and “High SES”. Despite the fact that respondents had the option of selecting all that applied, six of nine interview participants reported that they felt their school fell between categories since some students came from urban schools while some lived in distinctly rural areas and SES was variable. They felt confused and one participant reported that “the question really stressed me out”. One participant described her response to the question as “I don’t feel like I can really answer that, I mean, I would have to… check all of the boxes or something.” While another participant said, “Our students come from all kinds of backgrounds, so I didn’t really know, I wasn’t certain on how to answer that…to mark all of them or use our school data description? And, I don’t know if you want me to talk about my teaching this summer or if you wanted me to talk about the regular school year, since the student populations are very different.” This question was flagged for possible removal.

Re-worded items were Likert-Type items and included, “Use my understanding of cross-cutting concepts to better teach science from within an integrated STEM framework” and “Get students to become interested in STEM careers.” The first item, “Use my understanding of cross-cutting concepts” proved problematic from the perspective of interview subjects since they did not feel they had a good understanding of what this meant, for example, one participant said, “I didn’t really like that question because I know for me, I wasn’t sure what you were getting at there, if your meaning was like STEM subjects or what." As a result an explanation was provided in parentheses next to the question prior to the expert panel analysis.

The second item, "Get students interested in STEM careers" was identified by two interview participants as not being clearly an *integrated* STEM question, with one participant explaining that, "You don't have to teach STEM to get kids interested in STEM careers. You can do that with a field trip." The researcher decided to modify the question to "Get students interested in STEM careers through participation in integrated STEM learning", which was the form presented to the expert panel (Table 2).

Table 2: *Likert-type items flagged for removal prior to expert panel analysis*

Original Item	Reworded item
I am confident in my ability to use my understanding of cross-cutting concepts to better teach science from within an integrated STEM framework.	I am confident in my ability to use my understanding of cross-cutting concepts to better teach science from within an integrated STEM framework (cross-cutting refers to knowledge and intellectual tools that can be applied to multiple disciplinary areas.)
I am confident in my ability to get students interested in STEM careers.	I am confident in my ability to get students interested in STEM careers through participation in integrated STEM learning.

Participants reported no issues with survey format, though five of eight interviewees suggested a need for the inclusion of a definition of integrated STEM, with the common consensus being that when they were responding to prompts, they were not certain they were answering with a clear concept of the intended meaning of "integrated" STEM. The researcher made note of this, but did not change the survey prior to presenting it to the expert panel.

Electronic access to the survey was non-problematic. The survey was administered through an electronic link to the Qualtrics survey website. Overall, interview responses were consistent with survey responses with no survey participants indicating items which they felt should have been added or removed from the existing model beyond those previously discussed.

Validity. In the interest of time, the survey was content validated by an expert panel consisting of college professors with STEM backgrounds and advanced graduate students with both teaching experience and STEM backgrounds. Expert panels assume group judgment is superior to individual judgment, and that expert opinions can provide feedback suitable to guide research decisions (Rubio et al., 2003). The expert panel used a focus group format (Landeta, Barrutia, & Lertxundi, 2011) which is a planned discussion designed to acquire information about a specific topic (Krueger, 1994). Expert panels in the form of focus groups have the benefit of producing fast results (Williams, White, Kelm, Wilson & Bartholomew, 2006 in Landeta et al., 2011) and having high subjective validity (Krueger, 1994).

The expert panel was tasked with improving instrument validity by providing recommendations for omission, addition, and removal of items (Colton & Covert, 2007). The panel received the survey for consideration and comment prior to convening as a group. Once all of the panel members had time to thoroughly review the items, the panel was convened in a focus group session to reach consensus on the final format of the instrument. The objective was to identify any significant disagreements or lack of consensus among items with problematic items being modified into a best consensus format, flagged for consideration in later data analysis, and reported in the final research report, as was previously accomplished (Steyaert & Lisoir, 2005).

In developing an instrument, after the initial validation of the survey through an expert panel, it is a pre-test of scale on a representative sample of 100 to 300 or more participants (Spector, 1992; DeVellis, 1991). In the event pre-testing is not to occur, it is recommended that ratings produced by the expert panel be used in the place of pre-test results with the caution that panel responses may be dissimilar to a pre-test sample. In this study, the expert panel ratings were used to finalize the instrument to be administered to the participants being used to develop conclusions about teacher self-efficacy to teach integrated STEM since the results from the survey are considered preliminary and will be used to further develop the instrument in the future.

After a consensus session, the final survey model included a definition of integrated STEM in the initial survey instructions, which was also consistent with the results of the pilot survey. There were also changes in wording of some items for clarification and to ensure the questions were eliciting the intended responses; for example, on the item “I am confident in my ability to develop knowledge and skills necessary to teach science from within an integrated STEM framework”, the consensus was that, with the intent being a measurement of ability to achieve a future pedagogical piece rather than utilize a previously established pedagogical skill, that the word “new” should be added to the wording resulting in the final item, “I am confident in my ability to develop new knowledge and skills necessary to teach science from within an integrated STEM framework.”

Also, an explanation of cross-cutting concepts had been added to the survey, but was removed after the expert panel agreed that adding the definition removed the ability to measure whether teachers understood the concept in the first place. The final wording on this item was consistent with the original form (Table 2).

Common consensus also determined that two questions eliciting information about ability to develop assessments for use in integrated STEM contexts should be added to the survey. Two questions, “I am confident in my ability to formatively assess student learning of discipline-specific content while teaching integrated STEM”, and “I am confident in my ability to develop summative assessments to measure students’ integrative knowledge of STEM at the end of an instructional unit” were added to the survey. The final open-ended question was left worded as, “What do you think are the biggest challenges facing science teachers in integrated STEM teaching and learning environments?”

Once final consensus was reached, the survey was reformulated and the questions re-ordered such that questions intending to measure specific attributes of the pre-identified five general categories were not evident. The final instrument for wider distribution in the main study consisted of 30 items on a 1-4 Likert-type scale, 12 demographic items, and one open-ended item and was named the Self-Efficacy for Teaching Integrated STEM (SETIS) Instrument.

Reliability. Internal consistency reliability (homogeneity) was addressed using the Cronbach coefficient alpha (Cronbach, 1951). The correlation coefficient was used to look for strength of relationship between responses to items intended to measure the same construct, with an expectation that responses to similarly-worded constructs of this type should strongly correlate (Cohen et al., 2003). A correlation coefficient (r-value) greater than 0.70 was considered acceptable to establishing reliability of the survey (Cohen et al., 2003). Items with low reliability coefficients were to be discarded or re-written in later iterations of the survey (Bandura, 2006). Reliability statistics are discussed in the data analysis section below.

Participants. Participant teachers were selected from a convenience sample of active elementary, middle, and high school science teachers currently teaching STEM courses. Participants were recruited differently for each of the two phases of the mixed methods study with electronic participants being solicited via email and interview participants being solicited through the outreach of the county science coordinator.

After obtaining a letter of permission from the metropolitan school system in the convenience sample locale and IRB approval from the University of Tennessee, the SETIS questionnaire was distributed electronically to participants of science teacher associations in two southeastern states as well as to teachers in the convenience sample of the school system in the city where the university is located. Additionally, a paper format of the questionnaire was administered to teachers from a convenience sample at a large, state science association meeting. The purpose of paper-and-pencil administration was to have the opportunity to access a nonprobability (convenience) sample (Colton & Covert, 2007) to provide clarification on items if necessary, but also, due to the length of the survey, to elicit more dedicated response rates from participants. It is anticipated that there will be a high "no-response" rate to the emailed survey due to possible "survey fatigue" which may be related to the high volume of survey requests typically received by teachers across the school year.

Following data analysis, a small sample of participants (N=9) in the form of convenience-sample of science teachers currently teaching in a local, metropolitan school system were selected for open-ended interviews. Selection of these participants was preceded by a short telephone pre-interview or through recommendation by the district science coordinator ensuring the teachers actually have some understanding of integrated STEM teaching and learning relative to the definition provided in this research.

Data Collection

Once content validity had been established, the first, quantitative stage of the study was carried out. The first phase had the purpose of initially identifying and ranking in terms of influence, those factors that most affect teacher self-efficacy to teach in an integrated STEM framework. This phase consisted of administering the electronically delivered and the paper-and-pencil versions of the survey to identified participants. The electronically delivered survey was sent out through state science teacher association contacts in two southeastern states as well as to science teachers in the large, metropolitan school system within the community in which the university from which the research was being conducted is located. The paper-and-pencil survey was administered at a state science teacher association conference. Paper-and-pencil responses were manually entered into the SPSS v 22 program alongside electronically collected data resulting in a single dataset.

The second qualitative phase of data collection consisted of interviews used to inform conclusions and reveal possible inconsistencies in survey responses. These interviews were qualitatively analyzed after transcription using the methods of content analysis (Saldana, 2009) which aligns with the positivist approach to the constructivist perspective (Alvesson & Sköldberg, 2010) forming the foundation of a mixed-methods approach to social constructionism and self-efficacy theory adopted as the theoretical framework in this study(). Consistency between survey trends and interview responses were used to reinforce the reliability and content validity of survey items. Analysis of these data including qualitative, methodological approach is discussed in the next chapter.

CHAPTER IV - DATA ANALYSIS AND RESULTS

Summary

This section of the dissertation discusses the quantitative and qualitative analyses used to interpret trends and significance indicating evidential explanation in answer to the two research questions:

(1) What is the underlying structure of an instrument with acceptable validity and reliability for the measurement of the latent factors describing science teachers' self-efficacy to teach science within an integrated STEM framework?

(2) What are the constructs that define teacher self-efficacy to teach science within an integrated STEM framework?

Statistical Analyses

Quantitative Data Analysis

Brief Description of Participants. Respondents in this research project included 194 science teachers currently teaching grades pre-K through post-secondary in the southeastern, United States. Demographic tabulation reveals the entire description of demographic frequencies and descriptive statistics, (APPENDIX D) but some demographic factors are discussed in the results section below.

Statistical Data Analysis. Data were analyzed using SPSS 22, a statistical software package commonly used in survey data analysis. Likert-response items were organized into a database for statistical analysis. Descriptive statistics allow for indication of statistical estimates such a mean, standard deviation, and variance (Chromy & Abeycaserka, 2012). Measures of central tendency can indicate trends in data responses when displayed as a histogram (Lowry, 2005), providing valuable early insights into data indications.

Data cleaning techniques. Data were screened for outliers and missing data (APA Taskforce on Statistical Inference, 1999). Data were screened to identify common sources of error such as missing data, typing errors during data entry, column shifts, coding errors, and outliers. Also, the need to reverse-score items was assessed, but did not prove applicable due to the purposefully forward-worded nature of self-efficacy items. Recoding of open-ended or "other" responses also was completed. Due to the length of the survey and the open-ended questions, non-response was anticipated to be prevalent. Descriptive and frequency statistics were used to identify missing data, which were handled through use of valid percent in frequency analysis and listwise deletion of the item as noted later in the analysis. Of 194 responses, 156 (80.4%) consisted of complete datasets.

The Likert nature of the scale unsurprisingly eliminated outliers from the item responses, but it was necessary to throw out a few demographic responses due to their extreme nature. Specifically, one participant reported having taken 1000 hours of coursework in Technology and 700 hours of course work in engineering, while the next highest level of hours taken was 120 hours for technology, and 250 hours for engineering. Though reported numbers may well have been valid, as outliers, the numbers were highly unrepresentative of the rest of the sample and would likely have skewed the results. Similarly, one participant reported 150 math courses taught. Knowing that some participants were at or near retirement, it is very possible that this number was valid, but in the interest of keeping the data aligned with the larger portion of the sample and ideally the population the research intended, which had a second-highest report of 50 courses mathematics course taught, the response was deleted. Deleted items were treated as missing data.

Data were subject to frequency and descriptives analysis, analysis of means, a Mann-Whitney U test to look for gender differences, correlation analysis, factor analysis, and an ordinal logistic regression. Frequencies and descriptives were used on demographic items to describe the basic characteristics of the data and participants, and a qualitative frequency analysis was used to compare qualitative data to quantitative findings. Correlations were used to test for interdependence of test items and to make a decision about the type of rotation to use in the factor analysis. The factor analysis itself was used to reveal the latent variables explaining self-efficacy to teach integrated STEM as well as the underlying structure of the model. Ordinal logistic regression was used to identify group membership as well as to detect potential prediction models. Finally, item analysis for estimates of reliability using Cronbach's alpha ensured the items should be retained in the final instrument.

Demographics

As is common in education, the convenience sample was highly gender-biased (46 males, 147 female) with approximately 75% of respondents female (Table 3). Of this group, 87% (N=168) reported their race as white, with African-American being the next highest reported category at 8% (N=15). The remaining respondents identified themselves as either Hispanic/Latino (3%, N=5) or Asian/Pacific Islander (3%, N=5) (Table 4).

Table 3: *Demographics - Gender*

Gender	Frequency	Valid Percent
Male	47	24.2
Female	147	75.8
Total	194	100.0

Table 4: *Demographics - Race/Ethnicity*

	Frequency	Valid Percent
Asian/PI	5	2.6
Black/AA	15	7.8
Hispanic/Latino	5	2.6
White/Caucasian	168	87.0
Total	193	100.0

In terms of the grade-level distribution for teachers, 1.5% (N=3) taught Pre-K grades, 2.6% (N=5) taught grades K-2, 8.2% (N=16) taught grades 3-5, 12.9% (N=25) taught grade 6, 23.2% (N=45) taught grades 7-8, 40.7% (N=79) taught grades 9-10, 37.1% (N=72) taught grades 11-12, 11.9% (N=23) taught post-secondary courses, and 13.9% were not currently teaching. It should be noted that the percentages do not add up to 100% because of overlap in grades taught, for example, many 9-10 teachers also would teach grades 11-12, and some 9-10 and 11-12 teachers also teach post-secondary courses (Table 5).

Years of teaching experience was variable and included less than one year of experience (8%, N=16), 1-2 years of experience (8%, N=15), 3-5 years of experience (13%, N=24), 6-10 years of experience (21%, N=41), 11-15 years of experience (17%, N=33), 16-20 years of experience (9%, N=18), 21-29 years of experience (13%, N=25) and 30 years or greater of experience (10%N=20). (Table 6).

Table 5: *Demographics - Grade level taught*

Grade	Frequency
Pre-K	3
K-2	5
3-5	16
6	25
7-8	45
9-10	79
11-12	72
Post-Secondary	23

Table 6: *Demographics - Years of Teaching Experience*

Years of Teaching Experience	Frequency	Valid Percent
0	16	8.3
1-2	15	7.8
3-5	24	12.5
6-10	41	21.4
11-15	33	17.2
16-20	18	9.4
21-29	25	13.0
30+	20	10.4
Total	192	100.0

Across STEM disciplines, 20% (N=36) of participants had technology teaching experience, 12% (N=22) had engineering teaching experience, and 30% (N=57) had math teaching experience, while 16% (N=30) reported that they also taught other, non-STEM subjects (Table 7). Licensure results included 64% science (N=125), 4.6% technology (N=9), 6.7% mathematics (N=9), and 13% engineering (N=13) (Table 8).

Thirty-one percent reported teaching integrated STEM courses, which was less than the 41% reporting that they taught STEM courses in general. Forty-one percent of respondents reported being from a school where STEM was an explicit, school-wide mission of the school, with 37% reporting integrated STEM teaching and learning as a school-wide mission.

Table 7: *Demographics - Courses Taught in STEM Disciplines Outside of Science*

Discipline	Number of Courses Taught	Frequency	Valid Percent
Technology	0	148	80.4
	1-5	32	17.4
	>5	4	2.2
Math	0	127	69.0
	1-5	43	23.4
	>5	14	7.6
Engineering	0	161	88.0
	1-5	18	9.8
	>5	4	2.2
Other	0	154	83.7
	1-5	19	10.3
	>5	11	6.0

Table 8: *Demographics - Licensure Areas*

Discipline	Frequency
Science	125
Math	61
Technology	9
Engineering	13
Other	56

Mean Item Responses

Means and standard deviations of item responses were calculated and tabulated for comparison. Mean responses ranged from a high of 3.30 (SD = .590) on "c*onfidence in ability to get students to experience excitement, interest, and motivation to learn about phenomena in the natural world*" to a low of 2.85 (SD = .787) on *"confidence in ability to obtain materials necessary to teach science in an integrated STEM framework"* (APPENDIX D). In all the entire range of means was only .45 which will be discussed in detail in the following chapter.

Mann-Whitney U Test

A Mann-Whitney U test for gender effects was performed on the constructs kept in the final model. The Mann-Whitney U test is a "rank-based nonparametric test" suitable for use when ordinal dependent variables are present (Laerd, 2015). Additionally the data met the other assumptions for a Mann Whitney U test including a dichotomous independent variable, independence of observations, and a similar score distribution for both males and females, which was determined through examination of the histograms for each dependent variable on gender. The Mann-Whitney U test resulted in statistically significant median scores for three items: item

5 “*confidence in ability to use teaching experience to teach science effectively from within an integrated STEM framework*”, U = 2,677, z = -1.295, p = .036, item 6 “*confidence in ability to teach my content within an integrated STEM framework*” U = 2,352, z = -2.108, p = .035, and item 13 *“confidence in ability to meet evaluation requirements while teaching integrated STEM*” U = 3,287, z = 1.986, p = .047. Examination of median and mean scores showed that while median scores were the same for males and females, as a whole, males averaged at 3.18 versus 2.90 for women on item 5, 3.21 versus 2.92 on item 6, and 2.83 versus 3.10 on item 13.

Inter-item Correlations

Inter-item correlations using the Pearson Product Moment Correlation were tabulated and examined to identify degree of correlation between variables (APPENDIX H). Positive, significant ($p < .001$) correlations ranged from $r = 0.313$ to $r = 0.831$, with no items exhibiting multicollinearity $r > 0.9$ which would suggest the items actually represented the same variable. All correlations exceeded 0.3 supporting their inclusion in the later factor analysis. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.939 which Kaiser (1974) reports as superb, allowing for the rejection of the null hypothesis that there was insufficient correlation between variables; this further indicated the data were suitable for factor analysis (Table 9). Bartlett’s test of sphericity had a Chi-square of 3818.865 (df = 435, p >.001) supporting the null hypothesis that the correlation matrix was an identity matrix. This high level of significance further supported the decision to perform a factor analysis on the data.

Table 9: Suitability of Data for Factor Analysis

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.939
Bartlett's Test of Sphericity	Approx. Chi-Square	3818.865
	df	435
	Sig.	.000

Factor Analysis

An Exploratory Factor Analysis (EFA) with a varimax rotation was conducted on the 30 items included in the instrument to determine the fundamental structure underlying teacher self-efficacy to teach integrated STEM. Exploratory factor analysis was chosen in alignment with the purpose of identifying latent variables such as would describe self-efficacy. A varimax rotation was used consistent with the conclusion that there was no correlation between variables (Gray &Kinner, 2012) as revealed in the unrotated correlation matrix.

After listwise deletion of missing data, 156 observations were included in the analysis, exceeding the guidelines of 5 observations per variable (30 variables x 5 observations = 150 observations necessary to conduct factor analysis). A maximum likelihood extraction was used Egiven the number of observations per variable along with the subsequent interval nature of the data and that a goal of the analysis was to identify latent constructs in absentia of an established theory. The exploratory factor analysis produced a four factor solution explaining 62% of the variance when eigenvalues were accepted at >1, which was supported by the generated scree plot (Costello & Osborne, 2005). After removing problematic items, the final accepted solution contained three factors and explained 62% of the variance. The process leading to the final solution is described below and can also be found in APPENDIX E.

The initial solution after implementation of the varimax rotation retained a Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of .939, X^2 (435, N = 194) = 3818.865, $p < 0.001$). The communalities representing the amount of variance accounted for by accrued factors produced one item, "Confidence in ability to elicit support from supervisors to teach integrated STEM effectively" with a communality lower than the acceptable level of 0.45, supporting removal of this item from subsequent analyses. Once this item was removed, all items were within acceptable communality range (>0.45)

The subsequent iteration of the model, beyond producing acceptable communalities for all factors, produced a four-factor model explaining 63% of the variance in the model (KMO = .938, X^2 (406, N = 194) = 3743.851, $p = .000$). Problematically, ten items demonstrated complexity in the rotated factor matrix supporting removal of those items from the model. The remaining 19 items were subjected to a further analysis with eigenvalues of greater than 1 determining inclusion in subsequent models. After removal of the 10 complex factors, a three factor solution explaining 62% of the variance remained (KMO = 0.930 X^2 (171, N = 194) = 2235.495, $p = .000$) yet, three items still demonstrated complexity with loading slightly greater than 0.4 on two or more items. These items were removed and another analysis was run. This analysis resulted in a two-factor solution which, while parsimonious, only explained 56% of the variance, and upon examination, did not explain the model well, in that the remaining model was nonsensical. Therefore, it was decided that a three-factor solution explaining 62% of variance was the appropriate solution to best explain the model since each of the remaining three factors explained a considerable portion of the variance (27%, 19%, and 16% respectively). Beyond the explanation of variance, the KMO and communalities supported this model (Figure 1, Table 10).

The factors identified in the final model, which were categorized as “Social”, “Personal”, and “Material”. Each of these factors had at least four factors loading strongly (>0.5) on the item with ten factors loading strongly on Social. Social factor items were so named due to their nature as consisting of explanation of self-efficacy arising from influences outside the teacher and directed toward the improvement or assessment of others, while Personal were teacher-controlled influences relying upon internally located sense of ability, and Material primarily had to do with learning to use technology-related resources.” These are described in detail in the discussion section below.

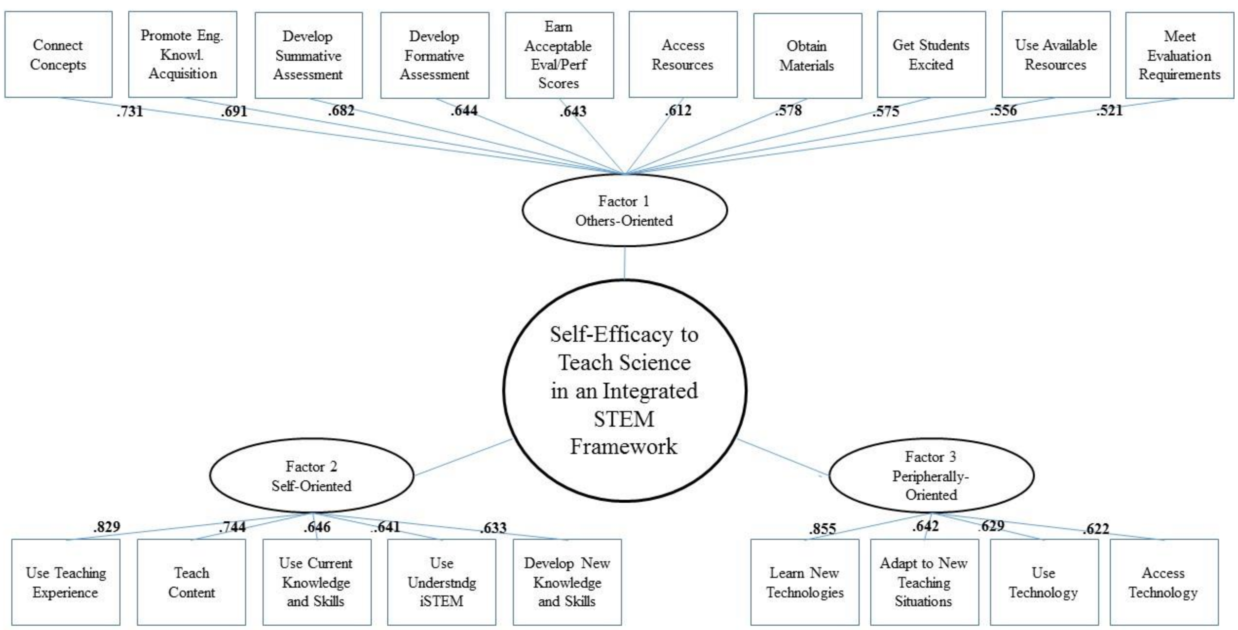

Figure 1: *Final Structural Model*

Table 10: *Final Model Loadings*

Item #		Factor 1	Factor 2	Factor 3
26	Connect Concepts	.731		
27	Promote Eng. Knowl. Acquisition	.691		
30	Develop Summative Assessment	.682		
25	Develop Formative Assessment	.644	.326	
28	Earn Acceptable Eval/Perf Scores	.643		
20	Access Resources	.612		
15	Obtain Materials	.578		
29	Get Students Excited	.575		
21	Use Available Resources	.556	.349	
22	Meet Evaluation Requirements	.521		.394
5	Use Teaching Experience	.377	.829	
6	Teach Content	.349	.744	
2	Use Current Knowl. & Skills	.403	.646	.324
4	Use Understanding of iSTEM	.421	.641	.305
3	Develop New Knowl. & Skills	.314	.633	.374
10	Learn New Technologies			.855
11	Adapt to New Teaching Situations	.383	.346	.642
14	Use Technology	.417		.629
12	Access Technology	.306		.622

Note: Extraction Method: Maximum Likelihood.
Rotation Method: Varimax with Kaiser Normalization.[a]
Rotation converged in 6 iterations

Logistic Regression

Cumulative Odds Ordinal logistic regression examined the influence of demographic factors (independent variables) on instrument item responses (dependent variables) after establishing that final data met assumptions including dependent variables being ordinal in nature, independent variables being categorical in nature, absence of multicollinearity, with proportional odds.

The first step in the regression was to create dummy variables using indicator (dummy) coding for categorical variables (Hardy, 1993) in order to test the assumptions of multicollinearity and proportional odds. Collinearity statistics did not reveal any evidence of excessive correlation between variables with all tolerance values greater than 0.1 and all variance inflation factors (VIF) less than 3.0.

The next step in the analysis was to run each item that remained in our three-factor solution through the GENLIN procedure in SPSS 21, which is a generalized linear model appropriate for use in logistic analysis of categorical methods, being similar to the Polytomous Universal Model (PLUM) procedure which, prior to the availability of GENLIN was more commonly used for ordinal logistic regression (Laerd, 2015). There was no evidence of model effects for most demographic factors on any of the items examined with the exception of Male Gender and Number of Course Hours in Math on Connecting science concepts across iSTEM disciplines, X^2 (3, N = 194) = 3.786, p = .032 and X^2 (1, N = 194) = 6.370, p = .012 respectively). Therefore it can be said that only Male Gender and Number of Course Hours in Mathematics have a statistically significant effect on the prediction of ability to Connect Science Concepts across iSTEM Disciplines. Goodness of fit tests were run on each item and demonstrated non-significance supporting the validity of the models $X^2(17, N=194) = 36.144$, $p<.004$).

One interesting finding was that the more strongly associated an item was with a particular factor, the more likely it was to find significant effects of that item on the odds ratio in parameter estimates. Speculation as to the meaning of the findings in terms of the self-efficacy instrument have been reserved for the later discussion section to follow.

Demographic factors were compared through analysis of parameter estimates (

Due to the number of items (19) being compared to demographic factors, significant results are displayed in tabular format below. As can be seen, having between one and two years of teaching experience was significantly related to response on several items including the Personal Factors "Use Teaching Experience" ($\chi^2(1) = 11.194$, $p = .001$), "Use Understanding of iSTEM" ($\chi^2(1) = 10.069$, $p = .002$), "Use Current Knowledge and Skills" ($\chi^2(1) = 10.432$, $p = .001$), "Teach Content" ($\chi^2(1) = 5.578$, $p = .018$), the Social " Connecting Science Concepts across iSTEM" ($\chi^2(1) = 4.625$, $p = .032$), "Meet Evaluation Requirements" ($\chi^2(1) = 7.203$, $p = .007$) and the Material "Adapt to New Teaching Situations" ($\chi^2(1) = 5.285$, $p = .022$) and "Access Technology" ($\chi^2(1) = 4.730$, $p = .030$).

Table 11: *Significant Demographic Categories*

Factor	**Item**	**Demographic Category**	**Upper and Lower Odds**	**Statistics** ***Chi-Square significance***	
Factor 2: Personal	Use Teaching Experience	< 1 yr teaching experience	.031 - .572	$\chi^2(1) = 7.352$	p = .007
		1 – 2 yr teaching experience	.017 - .346	$\chi^2(1) = 11.194$	p = .001

Table 11: *Significant Demographic Categories (Continued)*

Factor	**Item**	**Demographic Category**	**Upper and Lower Odds**	**Statistics *Chi-Square significance***	
	Use Understanding of iSTEM to teach science	1 – 2 yr teaching experience	.021 - .401	$\chi^2(1) = 10.069$	p = .002
		Experience teaching engineering	1.014 – 1.867	$\chi^2(1) = 4.208$	p = .040
	Use current knowledge and skills to teach iSTEM	1 – 2 yr teaching experience	.019 - .380		
	Teach content within iSTEM framework	Gender = male	1.127 – 4.905	$\chi^2(1) = 5.191$	p = .023
		< 1 yr teaching experience	.038 - .678	$\chi^2(1) = 6.202$	p = .013
		1 – 2 yr teaching experinece	.041 - .744	$\chi^2(1) = 5.578$	p = .018
		Experience teaching engineering	1.032 – 1.720	$\chi^2(1) = 4.835$	p = .028
	Connecting Science Concepts across iSTEM	Gender = male	1.078 – 5.014	$\chi^2(1) = 4.625$	p = .032
	Get Students Excited About Natural Phenomena	Number of course hours in math	1.010 – 1.083	$\chi^2(1) = 6.370$	p = .012
Factor 1: Social	Meet Evaluation	Gender = Male	.200 - .881	$\chi^2(1) = 5.261$	p = .022

Table 11: *Significant Demographic Categories (Continued)*

Factor	**Item**	**Demographic Category**	**Upper and Lower Odds**	**Statistics *Chi-Square significance***	
	Requirements				
		<1 yr teaching experience	.048 - .851	$\chi^2(1) = 4.751$	p = .029
		1 – 2 yr teaching experience	.032 - .584	$\chi^2(1) = 7.203$	p = .007
Factor 3: Material	Adapt to New Teaching Situations	1 – 2 yr teaching experience	.039 - .772	$\chi^2(1) = 5.285$	p = .022
	Access Technology	1 – 2 yr teaching experience	.049 – 26.796	$\chi^2(1) = 4.730$	p = .030

Reliability and Item Analysis

An item analysis was used to determine Cronbach's alpha reliability index on the three factors identified as a solution to the model in order to estimate internal consistency reliability of the final instrument. Reliabilities were .917 on factor 1 which contained 10 items, .918 on factor 2 which contained five items, and .878 on factor 3 with its four items (Table 12).

All alpha values fell into the category of exhibiting a high level of internal consistency (DeVellis, 2003). The item-total statistics demonstrating the contribution of each item to the scale can be seen in APPENDIX F. It was determined that the final model solution exhibited a high level of internal consistency and was a valid and reliable approximation of the constructs predicting self-efficacy to teach integrated STEM.

Table 12: *Reliability*

	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Factor 1	.917	.918	10
Factor 2	.918	.919	5
Factor 3	.878	.818	4

Qualitative Analysis

The qualitative interview question structure can be found in APPENDIX A. As described in the methods section of this document, data analysis methods of Bogdan and Biklen (1998) and the content analysis methods of Saldana (2009) were used to confirm that items included in the instrument actually demonstrated the ability to explain the true nature of participants' reactions and responses to the items and fulfilled the intent criteria of the items. The instrument itself contained one open-ended question to which 130 of 194 participants provided a response: "What do you think are the biggest challenges facing science teachers in integrated STEM teaching and learning environments?" This item was intended to allow participants to indicate factors they may have felt should have been included in the instrument that are connected to their own perception of self-efficacy to teach science in an integrated STEM teaching framework. This item was also used in conjunction with interview responses to identify potential factors that may need included in development of future versions of the instrument.

Bogdan and Biklen (1998, 2003) use a method of organizing data through line by line analysis of data accompanied by notations and coding, or identifying important themes. They define qualitative analysis as "working with data, organizing it, breaking it into manageable units, synthesizing it, searching for patterns, discovering what is important, and what is to be learned, and deciding what you will tell others." (Bogdan & Biklen, 1982, p.145).

In this research, interviews and open-ended items were transcribed and key words and phrases indicative of self-efficacy were highlighted and then arranged into categories and codes representative of larger themes. In qualitative research a code is "most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of a language-based or visual data" (Saldana, 2009, p.3) These codes were then organized into categories based upon their similarities or other shared characteristics (Saldana, 2009). Categories could then be grouped into larger themes creating a qualitative "structure" indicative of teacher self-efficacy to teach science in an integrated STEM framework.

Interviews with four high school, two middle school, and three elementary teachers were recorded and analyzed for the purpose of further content validity as well as to provide information useful to future development of the self-efficacy instrument. Demographic characteristics of the interview participants are not included in research reporting due to small sample size and the fact that all interview participants came from the same school system. It was determined that demographic information could unnecessarily compromise anonymity and confidentiality of participants. However, it can and should be noted that of the four high-school teachers interviewed, all but one had previously had a career in a STEM field, though even that individual was actually first a foremost trained in Physics, but ended up in mathematics education due to the need for math teachers. This characteristic will be of importance in the discussion of one of the emergent categories in the chapter to follow.

It was determined from elicited responses that items were consistent with their intent as written further supporting overall content validity. However there were some trends that indicated future administrations of the instrument should include some additional items. Frequency Analysis (Table 13) indicated the frequencies of codes aligning to emergent categories. Resources, Technology and Time combined to form the most frequently named challenges facing teachers as they attempt to participate in integrated STEM teaching and learning appearing 75 times among the 130 open-ended item responses, and also in every one of the qualitative interviews. Content knowledge, support, understanding of integrated STEM, pedagogical knowledge and skills, professional development, school culture, and standards requirements rounded out the top categories with greater than five incidents of mention as a specific challenge on the open-ended items, though only content knowledge, support, school culture, and professional development received attention in open-ended interviews. These qualitative categories are discussed and aligned with interview findings in the next chapter.

An important second category related to experience emerged in the interviews, and was named "career experience." It happened that the three interview participants coming from STEM careers mentioned professional experiences as contributing to their confidence in ability to teach integrated STEM, providing them with background knowledge and real-world scenarios that enabled them to feel a stronger sense of personal ability to transfer this authentic knowledge to their students. All secondary and one of two middle school interview participants mentioned exposing students to professionals from STEM careers as an important aspect of STEM teaching and learning. There are currently no items on the self-efficacy instrument measuring professional experience outside of education, which could have important implications in terms of the final model requiring some revision. This is discussed in detail in the next chapter.

Table 13: *Teacher Beliefs About Challenges in Teaching Science as Integrated STEM*

Category	Codes	Frequencies
Resources	financial, material, curricular	34
Technology	access (school), access (home)	24
Time	not enough, for planning, for collaborating	17
Content Knowledge	engineering, outside discipline, teaching content within iSTEM framework, technology	17
Support	administrative, political, parental	13
Understanding iSTEM	for teachers, integrating discipline-specific epistemologies, CK for iSTEM	11
Pedagogical Knowledge and Skills	discipline-specific, for iSTEM, questioning skills, elicit critical thinking	9
Professional Development	content	9
School Culture	poor fit, union influences, testing focus, time-dedicated to science in elementary settings, class size	9
Meeting Standards	standards and testing requirements	9
Thinking style	elicit critical thinking, differentiation, diversity	4
Assessment	student work, learning	3
Desire to Teach iSTEM	teachers, admin	2
Real-World Experience	for teachers, integrating discipline-specific epistemologies	2
Collaboration	school-level, external	2
Student Apathy	lack of desire	1

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A final, third category related to experience specific to elementary teachers interviewed was “classroom management”, which is understandable considering how younger students may not yet possess the maturity and self-direction to stay focused on the task at hand. Classroom management is further explored in the discussion section to follow.

The next category to emerge was what teachers felt students needed to know in order to actually be receiving an integrated STEM education. The 30-item instrument focused upon teaching science content within an integrated STEM framework, and while teachers were discussing their views on student knowledge, student challenges, and content delivery, phrases such as “habits of mind”, “STEM habits”, “skillsets”, “mastery”, “ownership”, and “understanding the big picture” emerged repeatedly. This suggests the inclusion of a construct which was subsequently named “STEM habits”, and either the writing or re-writing of some items to reflect the potential importance of this category.

Closely related to “STEM habits” was a category labeled “Facilitation of Student-Led Projects”. All teachers interviewed reflected upon the role of the teacher in guiding students in their attempt to negotiate self-directed and group-directed projects. Codes leading to the development of this category included, “produce a product”, “allowing them to solve problems”, “being a source”, “guide themselves”, “non-biased role”, “take on their own interests”, “let them do”, and several others which will be explored in detail in the discussion section to follow. This category may actually be a part of classroom experience.

A fifth category that may actually be part of the third category named “STEM habits” was labeled “Doing STEM”. This actually relates to one of the questions on the original 80-item piloted survey which included items related to defining STEM, but which were removed as not being appropriate for the intent of this research, which was to measure self-efficacy to teach integrated STEM. Nonetheless, interview participants, especially the middle school participants, seemed to have a notion that there were specific activities in which students should be engaged if they are truly participating in integrated STEM activities.

The next category to emerge confirmed the inclusion of items related to technology and the subsequent “Material” (Factor 3) that was found to be a solution to the final model. It should be noted that three of four items loading onto this factor were directly related to technology. All interview participants without prompting mentioned technology when they discussed both support and resources-related interview questions. While actually possessing adequate technology did not seem to be an issue for any of the teachers, knowing how to use it was a repeated code. One middle school teacher suggested he would need “a lot of support” in order to include technology into his teaching. A high school participant mentioned the importance of having time to learn to effectively use technology, in his case specifically environmental and chemical sensors due to their sometimes complex nature. This category was subsequently labeled “Technology” and is discussed in more detail in the next chapter.

The final emergent categories actually suggest that some of the items included in the 30-item instrument should be re-worded and re-included in the next administration of the survey. These categories were “Collaboration” and “Professional Development” which corresponded to the items “confidence in ability to collaborate effectively with other STEM teachers” and “confidence in ability to find professional development programs to acquire knowledge and skills for teaching integrated STEM” respectively. These items showed complexity on the factor analysis and so were removed. A discussion of the implications and potential causation are included in the discussion section to follow.

Final categories were consistent with items already included in the instrument with interview participants' responses supporting their retention in the final model solution given a lack of revisions due to inclusion of new items from categories identified above. These included "developing new knowledge and skills", "using teaching experience", "using understanding of what integrated STEM means", "motivating students", and "materials and resources". Each of these categories had multiple codes supporting their importance as larger constructs relevant to integrated STEM teaching and learning.

The open-ended question on the 30-item instrument showed results consistent with both the interview responses and the final model outcome. After coding and categorizing, a qualitative frequency analysis was performed to gain a general understanding of the structure of the response pattern. Key categories included "Resources", "Technology", "Time", "Content Knowledge", "Support", "Understanding Integrated STEM", "Pedagogical Knowledge and Skills", "Professional Development", "School Culture", "Meeting Standards", "Thinking Style", and "Assessment". Categories were not considered important if they had fewer than three codes loading onto them, though they were included in frequency table for later consideration.

Of the 12 categories emerging from the qualitative, open-ended responses, "Time", "School Culture", and "Thinking Style" all represented constructs not included on the 30-item instrument. It is especially notable that "Time" had the third-highest frequency behind only "Resources" and "Technology" which were both included in Factor 3. This reinforces the conclusion that time-related factors should be included in future development of the instrument, and that time may be a significant predictor and even a factor explaining teacher self-efficacy to teach integrated STEM.

CHAPTER V - DISCUSSION AND IMPLICATIONS FOR FUTURE RESEARCH

Summary

The final chapter in this dissertation critically discusses the major findings related to the research questions developed, draws conclusions about the strength of these findings relative to the instrument developed, and also discusses the implications of the research in terms of future development and direction for research. The purpose of this research was to provide a critical evaluation of the research questions:

(1) What is the underlying structure of an instrument with acceptable validity and reliability for the measurement of the latent factors describing science teachers' self-efficacy to teach science within an integrated STEM framework?

(2) What are the constructs that define teacher self-efficacy to teach science within an integrated STEM framework?

Teacher Self-Efficacy

Understanding the nature of teacher self-efficacy to teach in any context merits attention since self-efficacy, the expectation about abilities to perform actions or tasks such as teaching influences both amount and duration of effort put into those actions or tasks in the face of challenges (Bandura, 1997; 2002; Cannon & Scharmann, 1998; Enochs & Riggs, 1990; Pajares, 1996; Riggs & Enochs, 1989; Schwarzer, 1992). Self-efficacy theory has been found to apply to almost any action or task an individual undertakes and instruments have been developed to measure self-efficacy for many of these (Bandura, 1997, 2006; Enochs & Riggs, 1990; Schwarzer & Jerusalem, 1995; Schwarzer, Schmitz, & Daytner, 1999 in Skaalvik & Skaalvik, 2007; Skaalvik & Skaalvik, 2007). With integrated STEM education receiving increased attention and funding (GAO, 2013) it follows that the cry for teachers able to teach content within an integrated STEM framework is increasing (Berlin & Lee, 2005; NAS, 2013, Scholmann et al., 2013). Therefore, understanding teacher self-efficacy to teach science from within an integrated STEM framework is viewed as a worthy goal. Such an understanding is possible only if we are able to reliably measure teacher competency. The purpose of this dissertation study, therefore, was to develop and validate a survey to measure teachers' self-efficacy to teach science within an integrated STEM framework and to reveal the nature of those factors that influence these teachers perceived self-efficacy to teach science within an integrated STEM framework.

A thorough review of literature was carried out to first identify the constructs to be included in the instrument as described by DeVellis (2003; 2011). The constructs fell into the categories identified previously suggesting integrated STEM teaching and learning outcomes may be at least partially related to (1) pedagogical knowledge of teaching in an integrated STEM , (2) teacher attitudes, (3) perceived challenges, (4) integrated STEM model (e.g. problem-based, design-based, inquiry, etc.), (5) type of integration (e.g. curriculum v. context, etc.), (6) teacher content knowledge, (7) demographic factors such as experience, (8) and teacher beliefs.

After a cycle of critical reflection and review of established constructs with fellow graduate students, professors and colleagues a set of questions were developed specifically targeting self-efficacy relative to these constructs for further review. The original self-efficacy instrument contained 80-items on a 0-10 Likert-type scale with 0 being "cannot do at all" and 10 being "very confident I can do this", and was piloted on a convenience sample of summer institute teachers (N = 24). After the pilot, the instrument was consolidated to 28 Likert-type items of a scale of 1-4 with 1 being "cannot do at all" and 4 being "very confident I can do this" and 14 demographic items for presentation to the expert panel. The final 30 item, 12 demographic question instrument was administered electronically and through paper-and-pencil to 194 participants (APPENDIX B). Final responses were analyzed and compared to qualitative data to further content validation and reliability and to provide guidance for future instrument development.

Interpretation of Findings

Factors affecting self-efficacy

The second question that guided this inquiry was: What are the constructs that define teacher self-efficacy to teach science within an integrated STEM framework? The following section provides a discussion of findings, related to this question.

As was noted in the results, the sample population (n=194) was highly gender-biased with 46 (25%) male and 147 (75%) female respondents (one missing). It was important to keep this in mind for two reasons. First, there has long been research demonstrating that males and females have very different attitudes and beliefs about their math and science abilities based upon their gender (Bleeker & Jacobs, 2004; Hargittai & Shafer, 2006; Simpkins, Davis-Kean, & Eccles, 2006; Spencer, Steele, & Quinn, 1999). Second, with such a large difference in respondents 101 more females than males, it would be prudent to be sure to include consideration of gender effects when running statistical tests including demographic factors. Gender-discrepancy is common in education, with women far more likely to enter the teaching profession than men (Acker, 1983; Drudy, 2008; Sedlak & Schlossman, 1986; Wigfield, Battle, Keller, & Eccles,2002). This gender bias is especially notable in elementary grades at greater than 90% according to Beilock, Gunderson, Ramirez, and Levine (2010). For that reason, still considering the need for sensitivity to gender effects, it was determined that the gender distribution of the sample was probably fairly representative of the larger population of science teachers and thus gender effects were subject to analyses.

A Mann-Whitney U test for gender effects determined that males rated their self-efficacy on item 5 "*confidence in ability to use teaching experience to teach science effectively from within an integrated STEM framework*", U = 2,677, z = -1.295, p = .036, and on item 6 "*confidence in ability to teach my content within an integrated STEM framework*" U = 2,352, z = -2.108, p = .035, differently than did females, ranking themselves higher on these two constructs. Klassen and Chiu (2010) found and also cite Antoniou, Polychroni, and Vlachakis (2006) and Chaplain (2008) in determining that female teachers self-report higher stress levels than do male teachers (p. 743) which could partially explain why females may report less confidence in actual teaching activities than men. In other words, content-related confidence may be an independent factor creating complexity in items 5 and 6 which makes identification of gender effects related to confidence in using teaching experience or teaching content indistinguishable from confidence in these same abilities, but with the added layer of these actions occurring within an integrated STEM framework. On the other hand, men are known to enter and persist in STEM professions at higher rates than women (Beede, Julian, Langdon, McKittrick, Khan, & Doms, 2011; Riegle-Crumb & King, 2010; Reigle-Crumb, King, Grodsky, & Muller, 2012) which could be related to aspects of self-efficacy for STEM content that extends beyond STEM professions into beliefs about abilities to teach STEM content to others. However, given that gender decisions regarding STEM professions seems to be less related to ability and more-related to choice (Wang, Eccles, & Kenny, 2013), further investigation into this question is warranted.

Further providing an interesting angle to the gender question is that males rated themselves lower than women on item 13 *"confidence in ability to meet evaluation requirements* *while teaching integrated STEM*" U = 3,287, z = 1.986, p = .047. This directly supports one of the findings of this research: that self-efficacy resides in different places for factors that are based upon an individual's own beliefs about ability "Personal" versus how he or she feels others may perceive or affect those abilities "Social."

The logistic regression discussed below also indicates that gender is a significant predictor of ""*confidence in ability to connect science concepts across integrated STEM disciplines*". X^2 (3, N = 194) = 3.786, p = .032, with males scoring themselves higher (mean = 3.33) than females (mean = 3.12). It is possible then that the same aspects of self-efficacy that encourage more men to enter STEM professions than women translate to self-efficacy in ability to relate science concepts to other disciplines. This premise is supported by research by Wang et al., (2013) who found that individuals with combined high math and high verbal ability were less likely to enter STEM professions than were those with high math and lower verbal ability, but that females were much more likely to have combined high math and verbal ability than were males. This allows for the possibility that males with high math and high verbal ability forgo actual STEM careers and enter STEM-associated careers such as education in STEM subjects. Having a combined high math and verbal ability could translate to better ability to connect concepts across disciplines, which would support higher male self-efficacy were this more common in male than female STEM teachers: an interesting possibility for consideration in future research. Again, based on research finding as well as current STEM research discussed above, efforts in future iterations of the instrument should include attempts to better delineate between sub-components such as self-efficacy for STEM content and self-efficacy for STEM teaching.

Ethnic groups considered non-white minorities were also highly underrepresented in the sample. Of the 194 participants, 86% (n=168) reported their race as white with African-American/Black (n=15) being the next highest reported category at 8%. The remaining 6% was split evenly between Asian/Pacific Islander (n=3) and Hispanic/Latino (n=3). There was an "other" demographic selection with a completion field, but this received no responses and so was removed from the dataset. This too follows sociocultural patterns, which find fewer and minorities entering science and engineering fields in the first place (Clark, 1999). Tests for ethnicity/minority effects were not included due to small sample size.

Years of experience. Years of teaching experience was reported in eight categories including, less than one year of experience (8%, n=16), 1-2 years of experience (8%, n=15), 3-5 years of experience (13%, n=24), 6-10 years of experience (21%, n=41), 11-15 years of experience (17%, n=33), 16-20 years of experience (9%, n=18), 21-29 years of experience (13%, n=25) and 30 years or greater of experience (10%, n=20). (

Table 6) It can be noted that the category 6 – 10 years had the greatest number of respondents at 21% (n=41), but other groups were fairly normally distributed. Previous research demonstrates the importance of that gender and experience on teaching self-efficacy (Klassen & Chiu, 2010; Henry, Fortner & Bastion, 2012) supporting the finding of significant effects in these areas. As will be discussed later in the regression analysis findings, having 1 – 2 years of teaching experience seemed to be a significant predictor of self-efficacy related to *using teaching experience* ($\chi^2(1) = 11.194$, p=.001), *using understanding of integrated STEM* ($\chi^2(1) = 10.069$, p=.002), *using current knowledge of integrated STEM to teach science content in an integrated STEM framework* ($\chi^2(1) = 11.222$ p= .002), *teaching content in general in an integrated STEM framework* ($\chi^2(1) = 5.578$, p=.018), *meeting evaluation requirements* ($\chi^2(1) = 7.203$, p=.007, *adapting to new teaching situations* ($\chi^2(1) = 5.285$, p=.022), *and accessing technology* ($\chi^2(1) = 4.730$, p=.030). With the exception of technology access, it is immediately evident that all of the factors showing significance are aspects of confidence in ability that take time to develop and so would be expected to be different for novice teachers as compared to experienced teachers. This premise is supported by research conducted by Henry, et al., (2012) on novice, high school math and science teachers in which it was found that teaching effectiveness improved considerably over the course of the first four years of teaching. Given that teaching in an integrated STEM framework is a complex task, it can be predicted that novice teachers, who are more focused on the actual pedagogy of teaching itself including classroom management, organization, and other contextual concerns, would struggle more with integrated STEM teaching and learning. Jackson, Garrison, Wilson, Gibbons and Shahan (2013) examined setting up complex mathematics tasks in a manner that facilitated student opportunities for participation and learning throughout and beyond the task and found that whole-class discussions with higher quality learning opportunities for students depended upon teachers' abilities in setup of the task and establishment of the cognitive demand of the task. With integrated STEM as a complex teacher task, it can be anticipated that novice teachers would be less adept at setting up tasks as well as to having a strong pedagogical knowledge of how to ensure appropriately differentiated cognitive demands.

Grade level effects. In terms of the grade-level distribution for teachers (Table 14), 1.5% (n=3) taught Pre-K grades, 2.6% (n=5) taught grades K-2, 8.2% (n=16) taught grades 3-5, 12.9% (n=45) taught grade, 23.2% (n=45) taught grades 7-8, 40.7% (n=79) taught grades 9-10, 37.1% (n=72) taught grades 11-12, 11.9% (n=23) taught post-secondary courses, and 13.9% (n=27) were not currently teaching. It should be noted that the percentages do not add up to 100% because of overlap in grades taught, for example, many 9-10 teachers also would teach grades 11-12, and some 11-12 teachers also teach post-secondary courses. To preserve the fidelity of the instrument, teachers who taught post-secondary but did not have K-12 teaching experience were removed from the dataset. Those not currently teaching had multiple reasons including maternity leave, sabbatical, and military leave. Overall, it appears there was a fairly representative sample of the larger population.

Table 14: *Grade level taught*

Grade	Frequency
Pre-K	3
K-2	5
3-5	16
6	25
7-8	45
9-10	79
11-12	72
Post-Secondary	23

Grade-level effects are important because of the different demands and time allotments associated with science teaching in elementary, middle-school, and secondary science teaching. Duschl (1983, in Tilgner, 1990) over a quarter of a century ago noted that elementary science instruction was “low in quality and too infrequent to be effective” (p. 421). Tilgner (1990) then cites Hove (1970) as determining the three most cited factors having a negative impact on elementary science teaching as being “(1) Inadequate teacher background in science, (2) inadequate science equipment, and (3) inadequate time and space” (p. 421). Tilgner (1990) herself, in a study examining past barriers to elementary science education compared to those faced in the 1990s concluded that there is less dedicated science time in elementary schools and that when time was spent it was not of high quality. The reasons for this failing were attributed to “negative attitudes and feelings of inadequacy” (p. 428) which directly translate to feelings of self-efficacy, or confidence in ability to successfully perform a given task: here science teaching and learning.

A later study by Enochs, Scharmann, and Riggs (1995) found that elementary teacher self-efficacy for teaching science was related to college science course exposure, high school science exposure, instructional delivery decisions, and perception of science teaching efficacy. College course exposure was one of the factors considered in this research as potentially contributing to teacher self-efficacy to teach science in an integrated STEM framework. Given that integrated STEM teaching is complex in nature and requires navigation of multiple disciplines simultaneously, it logically follows that elementary attempts to engage in integrated STEM teaching and learning would face similar challenges even if only from the science aspects of these efforts. While elementary teachers are more likely to be trained in teaching multiple disciplines the depth of their knowledge in those disciplines could discourage teachers from moving away from established curricula for which their self-efficacy would be higher. Besides less content knowledge in science being required for elementary teaching, it is also known that math content knowledge is an area in which elementary teachers are lacking (Hourigan & Donoghue, 2015). It is possible that elementary teachers content knowledge in STEM disciplines may discourage attempts at incorporating integrated STEM lessons.

Further contributing to elementary reluctance to engage in integrated STEM education can be inferred from elementary science instruction research by Milner, Sondergeld, Demir, Johnson & Czerniak (2011) in which they early on cite the minimization of science instruction in elementary settings due to the emphasis on reading and mathematics teaching and learning. This was supported by one of the elementary interview participants in this study who stated that one of the major challenged in teaching science through an integrated STEM framework was more difficult due to the time restrictions imposed by mandatory mathematics and reading requirements (Will, 2015). The classroom curricular requirements were further pointed out by Michelle (2015) who also noted that mathematics and reading were system-wide priorities for elementary students mainly as dictated by state testing obligations. Furthermore, Will indicated that his choice of reading materials had been limited due to system-wide mandates on what books and readings had been included as required components. Interestingly, nothing arose in interviews as conflicts between mathematics, a system-wide mandate, and integrated STEM teaching. It may be that choice of texts is more influential on integrated STEM pedagogy in elementary years than is mathematics since literary texts tend to be contextually broad and often don't involve scientific principles. This is especially true for elementary-aged readings which are often aligned toward societal norms or child-development rather than acquisition of mathematical or scientific knowledge. This may support the idea that mathematics is more or less an explanatory language of science and thus fits into the "STEM" picture more easily than does reading which often has other goals than acquisition of mathematical and scientific knowledge.

Subject-matter. Upon examining teaching experience from a subject matter perspective, 12% (N=22) of participants had engineering teaching experience, 20% (N=36) had technology teaching experience, and 30% (N=57) had mathematics teaching experience. The number of teachers with mathematics teaching experience is likely the highest due to the inclusion of elementary teachers in the study. Elementary teachers commonly teach multiple subjects but only one grade level. It can be supposed that most of the 21% of traditional K-5 teachers, which was calculated by adding the frequencies for K-2 and 3-5, again noting overlap between these grades would be low, to establish the traditional K-5 elementary inclusion, make up most of the 30% with mathematics teaching experience. This would mean ±10% of 6-12 teachers would have mathematics teaching experience. Indeed, physics teachers commonly teach mathematics and some chemistry teachers would consider their content as being highly mathematically-based and so might consider themselves as having mathematics teaching experience. The number of teachers currently teaching STEM and integrated STEM courses was higher than expected, though it should be noted, the researcher in retrospect realized a distinction between stand-alone STEM courses and content taught within an integrated STEM context should have been made since different approaches are required when the intent is content learning. Future versions of the final instrument will take this into consideration when developing demographic items through use of language that clearly directs teachers in terms of the intent of the item.

The final frequencies for STEM teaching included, 41% reporting they taught STEM courses and 31% reporting they taught integrated STEM courses. Again, a distinction should have been made to determine how many reporting that they taught integrated STEM also reported teaching STEM in general. Aligning with the 41% reporting they taught STEM 41% also reported that they taught at a school where STEM was an explicit, school-wide mission, while 37% reported that integrated STEM was an explicit, school-wide mission.

This overlap between percentage of schools with a STEM mission and individuals reporting they taught STEM allows for some interesting conclusions to be drawn. It must be considered whether or not teachers are likely to try teaching STEM when it is not an explicit, school wide focus. This is especially interesting given the percentage of respondents reporting they taught integrated STEM. While 37% reported that integrated STEM was an explicit, school-wide mission, only 31% reported that they taught integrated STEM. This 6% difference suggests that perhaps integrated STEM is perceived as having a complex nature and/or being difficult to achieve. In other words, it could be that some individuals feel they fall short of the expectations of integration. Alternatively, it could be that some respondents taught at schools where integrated STEM was an explicit, school-wide mission, but that they themselves did not have responsibilities toward that goal. Evidence of this circumstance is present in a study by Scott (2012) who found that of 10 schools included in a case study analysis of student achievement, 50% approximated the "integrated" STEM approach in which STEM disciplinary content is integrated within content-specific courses while the other 50% had STEM as an elective with the goal not necessarily being specific content knowledge gains. This suggests that the latter half are teaching at schools with a "STEM-dedicated mission" while the former half are teaching at schools with an "integrated STEM-dedicated mission". Further complicating the issue is the current practice of moving integrated STEM education into Career and Technical Education (CTE). These efforts are geared more toward integration of STEM subject areas as means of developing STEM skills such as problem-based learning (Brand, 2008) and workforce preparation (Asunda, 2014) rather than on content learning. Therefore, the curricula being developed to support these efforts would likely require a great deal of adaptation before they would be suitable for teaching standards-based science content. It should be remembered that self-efficacy for teaching content in an integrated STEM framework was significantly different for males and females with mean ratings of 3.21 ($N = 43$, $SD = .638$) for males and 2.92 ($N = 136$, $SD = .780$) for females providing additional reason to examine self-efficacy for content teaching in an integrated STEM context versus simply teaching integrated STEM as in a stand-alone course without testing expectations or required standards.

Teaching integrated STEM is complex in nature, which was established in the review of literature previously in this dissertation. Because of this, some teachers may feel they are falling short of achieving integrated STEM teaching and learning goals despite this being a school focus. The way the current study was set up in terms of demographic questions disallows for the distinction between whether teachers are supposed to be teaching their content in an integrated STEM school and feel they are not doing so, or if they are not teaching in an integrated way because this is not the approach the school takes toward STEM education. This is definitely an area that should be the subject of future research and may be related to some of the self-efficacy responses on the main instrument items, warranting closer examination and adaptation in subsequent instrument development.

Inter-Item Correlations

Inter-item correlations using the Pearson Product Moment Correlation were used to reveal correlations between variables. Significant correlations ranging from $r = .0313$ to $r = 0.831$ ($p < .001$ on all correlations) with no items exhibiting multicollinearity ($r > 0.9$) and all correlations exceeding $r > 0.3$ supported inclusion of all items in later factor analysis. Inclusion of all items was further supported by KMO of 0.939 which is reported as “superb” (Kaiser, 1974), and Bartlett’s Test of Sphericity with a Chi-square of 3818.865 ($df = 435$, $p > .001$) meaning the correlation matrix was not an identity matrix. The importance of this group of correlation outcomes lay primarily in the fact that these conditions were necessary in order to support the suitability of the data for factor analysis (Beaumont, 2012).

An Exploratory Factor Analysis with a varimax rotation was performed on the 30 Likert-type items included in the instrument in order to expose the latent variables describing the underlying structure of teacher self-efficacy to teach science within an integrated STEM framework. As mentioned previously, Exploratory Factor Analysis was chosen over the more commonly selected Principal Components Analysis because Exploratory Factor Analysis explicitly seeks to uncover the structure of underlying latent variables rather than to confirm pre-established theory (Fabrigar, MacCallum, Wegener, & Strahan, (1999). Self-efficacy can be described as being comprised of latent factors since self-efficacy cannot be observed or otherwise directly measured. Principal Components Analysis is technically not the preference for factor analysis since it only seeks to reduce the number of variable and not to identify underlying structure, which is why the distinction is typically made between the two, though results are often similar (Beaumont, 2012, Costello & Osborne, 2005). Costello and Osborne (2005) note that Principal Components Analysis is popular due to the nature of it being both the default setting and being easy to interpret, however, it is not viewed as a true method of factor analysis (p.2). While Principal Components Analysis is frequently used in an exploratory manner, it does not allow for modeling of factor structure when latent variables are involved (O'Rourke, Hatcher, & Stpanski, 2005).

Principal Axis and Maximum Likelihoods extractions were more appropriate for an Exploratory Factor Analysis, though other methods are available. Maximum Likelihoods was the final selected model since this method allows for goodness of fit indexes and significance testing of both factor loading and correlations among factors with confidence intervals (Fabrigar, et al., 1999, p.277).

The varimax rotation was used based on the assumption by the researcher that since the goal was to expose underlying latent factors, there would be an assumption of lack of correlation between variables. This was confirmed by examining the unrotated factors in the initial run of the data through the Maximum Likelihoods extraction, which confirmed a lack of correlation between items (Gray & Kinnear, 2012).

This resulted in the initial four-factor solution explaining 63% of the variance among items with eigenvalues greater than 1. After multiple iterations after removing items with communalities lower than 0.45 and items that loaded heavily (>0.4) on more than one item, the final chosen model consisted of a three-factor model accounting for 62% of the variance. The procedures for reaching this model are explained in greater detail in the results of the previous chapter.

Reviewing the results of the factor analysis allows for a more in-depth analysis of the final three-factor model (Figure 2). The factors were labeled “Personal”, “Social”, and “Material”. Each factor had at least four items loading strongly (>0.5) on that factor with factors labeled after examination of the items loading on it and their possible relationships, which deserve detailed explanation.

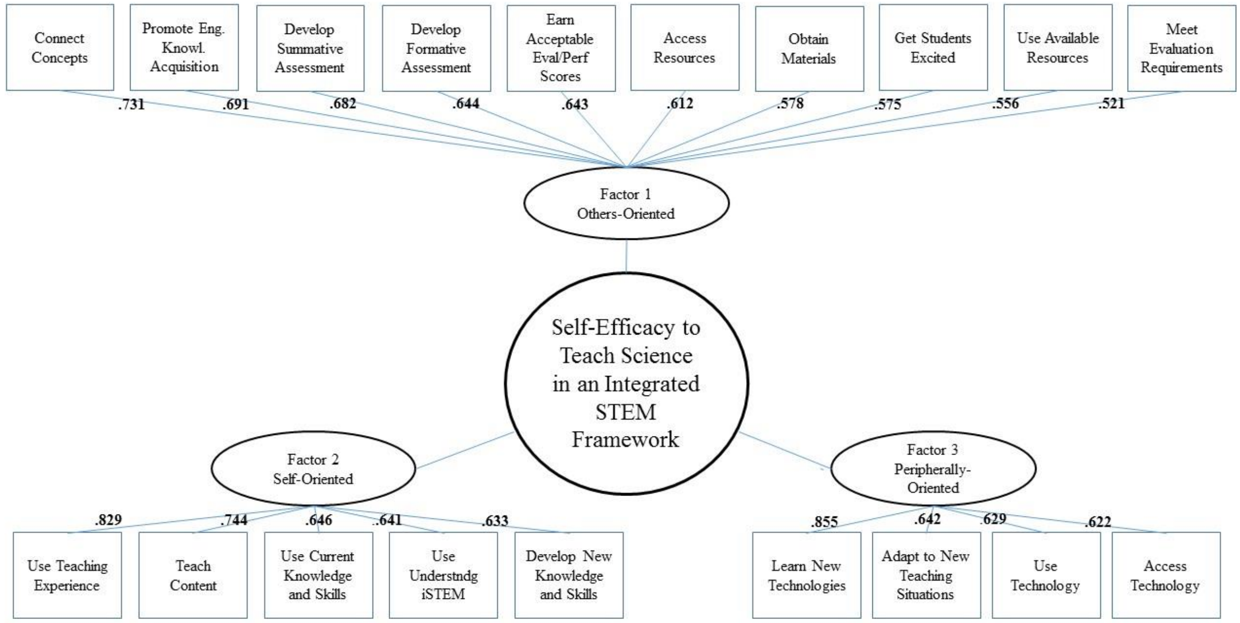

Figure 2: Final 3-factor model with rotated loadings

Factor 1: Social. Social (Table 10) consisted of the items corresponding to teacher confidence in ability to connect science concepts to those of engineering, mathematics, and technology, ability to promote students' grade-level acquisition of core engineering knowledge, develop summative assessments to measure students' integrated knowledge of STEM at the end of an instructional unit, formatively assess student learning of discipline-specific content while teaching integrated STEM, earn acceptable teacher evaluation/performance scores while teaching science in an integrated STEM framework, access resources necessary to teach science within an integrated STEM framework, obtain the instructional resources such as lesson plans necessary to teach STEM in an integrated way, get students to experience excitement, interest, and motivation to learn about phenomena in the natural world, use currently available resources to provide students with technology to engage in learning within an integrated STEM framework, and meet evaluation requirements while teaching integrated STEM.

This factor was labeled “Social” because they were all related to aspects of self-efficacy that were not entirely within the teachers’ control. The first item which loaded the most strongly on Social (Loading = 0.731) was teacher confidence in ability to connect science concepts to those of engineering, mathematics and technology. This item was initially problematic in this category since it seems to be related to teacher content and experiential knowledge. However, upon further examination, it became evident that connecting concepts requires knowledge of individual student life-experience and worldview. Teachers struggle to find concepts relevant across diverse student populations and connecting concepts requires that the teacher have a working understanding of the prior knowledge level and experiences of individual students in his/her classroom. Therefore, it is unsurprising that teachers would respond to this item as an externally-driven category.

The second most strongly loading item was ability to promote students’ grade-level acquisition of core engineering knowledge (Loading = .691). This item has clear association with self-efficacy being at least partially attributable to student outcomes. “Grade-level acquisition” suggests that there are specific standards that students must meet in order to be considered proficient in core engineering knowledge. Considering that core engineering knowledge is a relatively new concept for teachers, along with the fact that only 12% of teachers reported having engineering teaching experience, it can be expected that this item would play an important role in establishing teacher self-efficacy to teach integrated STEM.

The next item was confidence in ability to develop summative assessments (Loading = .682) to measure students’ integrated knowledge of STEM at the end of an instructional unit. This too is a student-centric item that is linked closely to individual belief in ability to perform a task, which supports its emergence as an important item in predicting self-efficacy. While ability to develop a summative assessment is teacher-centric characteristic, measuring individual students again requires knowledge of each student, their experience, abilities, and worldview. Therefore, the item itself falls outside of teacher autonomy (intrinsic factors) and thus is categorized as Social.

Similarly, the item measuring confidence in ability to formatively assess student learning (Loading = .644) of discipline-specific content while teaching integrated STEM relies upon teacher knowledge of individual students and student performance outcomes on a day to day basis, and so is not entirely within the control of the teacher. Following the logic of the previous item, it follows that confidence in ability to formatively assess students would emerge as a latent variable in the category of Social.

Likewise, confidence in ability to get students to experience excitement, interest, and motivation to learn about phenomena in the natural world (Loading .575) is not a characteristic that teachers can entirely control. Despite the best laid plans of teachers and the engaging nature of materials provided, some students may not be interested in the content and may not have an interest in the natural world from the most fundamental level. Again, student orientation toward interest in the natural world pulls this item away from teacher control (intrinsic) and more toward extrinsic control, thus landing this factor in Social.

The next item shifts away from student attributes and moves towards another external association, meeting evaluation requirements. Confidence in ability to earn acceptable teacher evaluation/performance scores while teaching science in an integrated STEM framework does certainly require that teachers have a certain level of pedagogical content knowledge and pedagogical knowledge and skills, but the extrinsic factors are obvious: teachers rely on their own ability to teach well on any given day, but evaluation itself is a very subjective process and therefore exhibits a categorization as a factor beyond the control of the teacher. The item confidence in ability to meet evaluation requirements while teaching integrated STEM (Loading = .521) mirrors the previous item in that it relies on the subjective observations of external parties.

The items access to resources necessary to teach science within an integrated STEM framework (Loading = .612), and obtain the instructional resources such as lesson plans necessary to teach STEM in an integrated way (Loading = .578) are both representative of characteristics beyond the control of the teacher. Accessing resources and obtaining materials both require monetary, materials, curricular, space, and other variables that are almost entirely budgetary in nature and so cannot be controlled by the teacher. This warrants their inclusion in Social.

Factor 2: Personal. Personal (Table 10) consisted of the items corresponding to teacher confidence to use teaching experience to teach science effectively in an integrated STEM framework, teach content within an integrated STEM framework, use current knowledge and skills to teach science in an integrated STEM framework, use understanding of integrated STEM to teach science effective in an integrated STEM framework, and develop new knowledge and skills necessary to teach science in an integrated STEM framework.

Examination of these items reveals that they are appropriately categorized as Personal because they fall within the arena of Pedagogical Knowledge and Skills and Pedagogical Content Knowledge. The most strongly loading item (Loading = .829) was confidence in ability to use teaching experience to teach science effectively in an integrated STEM framework. Teaching experience is entirely a construct directly related to teacher control since time on the job cannot be attributed to outside factors. Experience itself carries important weight in development of high self-efficacy (Bandura, 1997, Pajares, 2002) since it operates at multiple levels to influence belief in ability to perform certain actions and tasks.

The next item loading on Personal was confidence in ability to teach content within an integrated STEM framework (Loading = .744). This is another factor that arises from teacher belief in self and self-attributes with no attribution to external variables. Ability to teach content has to do with content knowledge, which emerges from learning and experiences, while ability to teach could also be self-attributable to pedagogical knowledge and skills. Similarly, the next three items loading on Personal, confidence in ability to use current knowledge and skills to teach science in an integrated STEM framework (Loading = .646), confidence in ability to use understanding of integrated STEM to teach science effectively in an integrated STEM framework (Loading = .641), and confidence in ability to develop new knowledge and skills necessary to teach science in an integrated STEM framework (Loading = .633) all follow the logic of assigning self-established strengths and characteristics to intrinsic attributes. All of these abilities are within the control of the individual and theoretically immune from outside influence.

Factor 3: Material. The third factor was labeled “Material” due to the fact that three of the four items loading strongly on this factor were directly related to the ability to learn, use, and access technology, all things that reside outside of individual or social control (Table 10). In qualitative responses to be described later in this paper, technology fell strongly into the resources category. The fourth item, confidence in ability to adapt to new teaching situations, loads fairly strongly on Material (Loading = .642) but is a little less easily explained. Indeed, one of the items loading acceptably on this factor, confidence in ability to use technology to teach science from within an integrated STEM framework (Loading = .629), showed some complexity, loading at .417 on Social. When looked at together, ability to adapt to new teaching situations and ability to use technology, which suggests taking learning of technology and being able to apply it in classroom contexts, supports the idea that "learning new things" may be an important construct of its own and should be considered in future instrument development.

This idea of "learning new things" could be said to describe three of the four items describing the factor Resource-Related, with the most weakly loading item, confidence in ability to access technology to teach science from within an integrated STEM framework (Loading = .622), being an obvious outlier from the other three items, though the loading is not substantially different and the item shows no complexity. This justified retaining the label "Peripherlly-Oriented" for this factor until future iterations of the instrument. Ability to adapt can be justified as a resource since adaptability requires appropriation of existing resources in the absence of more preferred alternatives.

Acceptance of Final Model

Acceptance of the final-three factor model (Table 10) containing the factors "Social", "Personal", and "Material" and their associated items was based upon the quantitative finding that in the absence of unacceptable levels of communality (< 0.45) or complexity on the rotated factor loadings (Loadings > 0.5 on at least one factor and <0.4 on subsequent factors, a model solution explaining 62% of the variance was superior to all other models generated, including forced two and four factor models. Furthermore, upon analysis of the items explaining the model, it was determined that the three factor model could be considered to have explanatory power from a theoretical basis originating from self-efficacy research, which was the goal of instrument development in this research.

Analysis of Means

The mean item responses were tabulated for comparison (APPENDIX D). Mean responses ranged from a high of 3.30 (SD = .590) on "c*onfidence in ability to get students to experience excitement, interest, and motivation to learn about phenomena in the natural world*" to a low of 2.85 (SD = .787) on *"confidence in ability to obtain materials necessary to teach science in an integrated STEM framework".*

As can be seen in the table above, on items 29, 10, 11, 26, 3, 14, 28, 12, 22, and 4 participants on average ranked themselves as being somewhat to very confident in abilities, or self-efficacy for those items. Items 6, 25, 5, 2, 20, 30, 21, and 27 participants ranked themselves at the high end of "would have difficulty doing this."

A Mann-Whitney U Test for Gender was tested for the constructs kept in the final model: this is a "rank-based nonparametric test" suitable for use when ordinal dependent variables are present (Laerd, 2015). Additionally the data met the other assumptions for a Mann Whitney U test including a dichotomous independent variable, independence of observations, and a similar score distribution for both males and females, which was determined through examination of the histograms for each dependent variable on gender. The Mann-Whitney U test resulted in statistically significant median scores for three items: item 5 "*confidence in ability to use teaching experience to teach science effectively from within an integrated STEM framework*", U = 2,677, z = -1.295, p = .036, item 6 "*confidence in ability to teach my content within an integrated STEM framework*" U = 2,352, z = -2.108, p = .035, and item 13 *"confidence in ability to meet evaluation requirements while teaching integrated STEM*" U = 3,287, z = 1.986, p = .047. Examination of median and mean scores showed that while median scores were the same for males and females, as a whole, males averaged at 3.18 versus 2.90 for women on item 5, 3.21 versus 2.92 on item 6, and 2.83 versus 3.10 on item 13.

Table 15: *Mean Item Responses for Final Model Constructs*

Item Number	N	Minimum	Maximum	Mean	Std. Deviation
29	175	2	4	3.30	.590
10	177	1	4	3.29	.724
11	177	1	4	3.27	.687
26	174	1	4	3.17	.649
3	181	1	4	3.15	.749
14	176	1	4	3.09	.724
28	175	1	4	3.08	.690
12	169	1	4	3.06	.814
22	176	1	4	3.03	.724
4	182	1	4	3.02	.786
6	179	1	4	2.99	.757
25	175	1	4	2.97	.738
5	182	1	4	2.97	.750
2	182	1	4	2.96	.723
20	176	1	4	2.95	.770
30	166	1	4	2.94	.694
21	176	1	4	2.92	.796
27	175	1	4	2.86	.753
Valid N (listwise)	156				

Logistic Regression

Ordinal Logistic Regression was used to reveal relationships between independent, demographic variable such as gender and ethnicity on responses to dependent item variables represented by the confidence ratings. The reasons for choosing an ordinal logistic regression are discussed in the results, but the reader should be reminded that linear regression models require at least one continuous variable and so were not appropriate for the analysis.

Model effects for the independent variables Gender (Male) $X^2(3, 47 = 3.786, p = .032)$ and Number of Course Hours in Mathematics $X^2(1, 187 = 6.370, p = .012)$ were significant relative to item 26, the predictor "confidence in ability to connect science concepts across integrated STEM disciplines, with males ranking themselves higher (M = 3.33 as compared to females M = 2.92) The gender aspect may be related to the fact that males are somewhat of an underrepresented group in the sample. It could also be linked to the fact that fewer males make up the elementary population and so would be expected to have taken more math courses for upper level teaching. Number of course hours in mathematics and science has been shown to be a significant predictor of pedagogical contentment with ability (Nadelson et al., 2012). Given that mathematics is the explanatory language of science, technology, and engineering, the finding that number of course hours in mathematics predicts confidence in ability to connect science concepts across STEM disciplines is unsurprising.

As was mentioned in previous chapter and is demonstrated in

, teaching experience, particularly having 1-2 years teaching experience, is a significant predictor the response items "Confidence in ability to use teaching experience to teach science in an integrated STEM context", "Confidence in ability to use understanding of integrated STEM to teach science effectively", "Confidence in ability to use current knowledge and skills to teach science from within an integrated STEM framework", "Confidence in ability to teach content from within an integrated STEM framework", "Confidence in ability to connect science concepts to those of engineering, mathematics, and technology", Confidence in ability to meet evaluation requirements while teaching integrated STEM", "Confidence in ability to adapt to new teaching situations such as those necessary to teach science from within an integrated STEM framework, and “Confidence in ability to access technology to teach science from within an integrated STEM framework.

This relationship is not unexpected given the fact that experiences are two of the four most important categories in determining personal expectations of ability, specifically mastery experiences which arise after successfully accomplishing a task or from vicarious experiences in which one observes another successfully accomplishing a task and can visualize him/or herself accomplishing the same thing (Bandura, 1994; Pajares, 2002). The fact that teachers with less than one year experience did not show significance on all but “Confidence in ability to use teaching experience to teach science within an integrated framework”, and “Confidence in ability to teach content within an integrated STEM framework” could be due to the fact that these teachers do not yet have enough class-time to evaluate their abilities, or that they have come from another profession and entered teaching, which the qualitative results suggest is a major factor influencing self-efficacy to teach integrated STEM. Future versions of the instrument should consider parsing these possibilities. Nonetheless, it is not surprising that novice teachers showed significance on either of these items, and this outcome supports the reliability of the instrument. After all, it would be expected that novice teachers would not have a high self-efficacy for using teaching experience, since they have very little, nor have confidence in ability to teach content within an integrated STEM framework, which is a complex task and requires practice and refinement, in other words, experience.

Another demographic showing significance on “Confidence in ability to teach content within an integrated STEM framework” was individuals with experience teaching engineering (Chi-square(1) = 4.835, p = .028). As one of the respondents reported on the open-ended question, “it seems engineering is the one subject that can truly be integrated across STEM disciplines." Often, engineering tasks are design-based or problem-based in nature and are seeking to solve a scientific problem using mathematics, with technology being the platform through which this is accomplished. Therefore it might be concluded that those with engineering teaching experience would be less daunted by ways to successfully achieve integrated STEM teaching and learning.

Reliability

An item analysis was used to determine Cronbach's alpha on the three factors identified as the solution to the model as an estimate of internal consistency reliability. Reliabilities were strongly supportive of the identified solution (Table 12: *Reliability*

). Factor 1, *Social* with its ten items had a reliability of .917, Factor 2, *Personal*, had a reliability index of .918 with its five items, and Factor 3, *Material*, had a reliability index of .878 with its four items. Post-removal r-values for individual items supported retention of all items in the final model (APPENDIX F). The final conclusion was that the final model solution exhibited a high level of internal consistency and thus is a valid and reliable approximation of the constructs predicting self-efficacy to teach integrated STEM.

The reliability analysis supports the prior analyses performed on the factors and items, but further supports the conclusions drawn about the nature of the statistical findings. First, it should be noted that the highest reliability coefficient was for *Social* ($r = .918$). This factor had the strongest loading items (.829, .744, .646, .641, .633), though complexity remained an underlying problem. Virtually equivalent in terms of reliability was Personal ($r = .917$) with nearly as strong factor loading from its ten items (.731, .691, .682, .644, .643, .612, .578, .575, .556, and .521). Finally, Factor Three, Material, had the lowest reliability coefficient ($r = .878$), though this is still considered good reliability ($r > .70$). It should be recalled that Material

(Loadings = .855, .642, .629, and .622) was the most problematic in terms of practical explanations and will be the subject of revision in future models. Especially considering the qualitative finding discussed below in the open-ended responses that Material, those beyond a teachers' control seemed to be the most important barrier to successful integrated STEM teaching and learning and so can be predicted to have an important effect on self-efficacy.

Qualitative Discussion

Qualitative data were collected through the open-ended item, "What do you think are the biggest challenges facing science teachers in integrated STEM teaching and learning environments?" and through semi-structured interviews. 130 of the 194 survey participants responded to the open-ended question. Participants' responses were indicated through use of the labeling P1 – P194 with P designating "participant" and the number designating their position in the dataset. Semi-structured interviews were conducted on nine participants who have been assigned pseudonyms: four were secondary science teachers ("Nathan", "Carol", "Tom", and "Samuel"), two middle school teachers ("Roger" and "Anna"), and three elementary teachers ("Joseph", "Will", & "Michelle"). The purpose of the open-ended item was to elicit information regarding other challenges or barriers to integrated STEM teaching and learning that may not have been included on the instrument. Interviews were used to support open-ended responses and also to further assess the content validity of the instrument. The open-ended responses fit the structural model of the instrument supporting the idea that self-efficacy is centered around the three emergent factors: a factor related to self and self-abilities, which was named "Personal Factor", a factor related to interactions with others including students, other teachers and administrators, which was the "Social Factor", and a third factor related to having access to external resources such as technology, materials, curriculum, and time, which was the "Material

Factor." As will be discussed below, self-efficacy for integrated STEM science teaching seems to depend upon not only beliefs about self and self-abilities, but in being able to negotiate a world with influences from other which relies in part on the abilities of others, and in beliefs about ability to obtain external items viewed as necessary or at least valued for complex teaching activities.

Material

The third factor containing constructs that at least partially explain teacher self-efficacy to teach science in an integrated STEM framework is actually discussed first in this section because, though it only had four items loading on it, it did appear to have the most importance based upon open-ended and interview responses. In the open-ended responses this emerged as the theme "*Resources*". This theme contained an important category, "*time*" which was not included in the instrument.   Discussion of the importance of Material, those constructs which are not necessarily under one's own control, but that affect beliefs about abilities, self-efficacy, are the subject of the next section of this research.

Resources. The most prominent theme emerging from the qualitative research was that of resources. Not only was "*Resources*" its own category, but two other categories including "*Technology*", and "*Time*", rounded out the top three most frequently occurring categories. These three categories were consolidated into a single theme named "*Resources*". In examining this theme, some general conclusions appear to be supported and are discussed.

The category "*Resources*" itself, consisted of open-ended responses falling under three codes, "*financial*", "*material*", and "*curricular*". Some responses on open-ended items included: "Resources and financial constraints" (P18), "Obtaining necessary supplies and materials" (P24), "Money for supplies" (P41), "Access to necessary materials" (P63), "Curriculum constraints"

(P159), and "Scope of Curriculum" (P154). There were multiple other similar responses totaling a frequency of 34 incidents (26%, N = 130) in which this category was indicated as having importance. This was by far the most highly invoked category with the next closest, "*Technology*" at a frequency of 24 (18%, N = 130).

In looking at interview data, a similar trend toward the importance of resources can be seen as evidenced in by comments from Nathan who responded to a follow-up question eliciting information equivalent to the open-ended item in that the question allowed the participant to provide feedback on any aspect that would improve integrated STEM teaching. When asked by the question, "So if there was something that you thought would help you improve in integrated STEM teaching, what would it be: out of anything? Out of any aspect?" Nathan responded, "Well the biggest thing: Resources. Time." When prompted to further this idea, Nathan continued, "Well, resources, I guess space could be one, time could be a resource, and having the right equipment is always necessary. Especially if you are trying to do a project and you have to go back and figure out how do that project with the equipment you have."

As can be seen in his comments, Nathan supported the open-ended responses of other teachers who not only felt material resources were necessary to teaching science in an integrated STEM framework, but also brought up the importance of time, which is discussed in detail later. Curriculum as a resource can also be seen in the comments of Nathan who further stated how important it is to, "find projects that are relevant for students, and meaningful."

Carol has a similar set of comments regarding resources and expanded the idea by including other resources in terms of her suggestion that resources include "access to scholarly publications", which can be seen to encompass both material and curricular codes. Carol also mentioned access to professionals, laboratory materials, financial constraints, and materials support to facilitate student-generated projects which may require resources outside of those currently on hand at the school.

Tom spent a great deal of time discussing the importance of curricular resources available through a fellowship within a new science teacher academy of a national science organization as being particularly important to his early development as a teacher. He felt that both curricula targeting specific content and just general lesson ideas were of such value that a subscription to the resources site was maintained post-fellowship. Furthermore, Tom particularly noted that teaching ideas arising from co-teaching opportunities also played an important role in later integrated STEM teaching confidence, “They [co-teachers] have always been good resources for content ideas, but also for STEM modeling, teaching, and for me, their methods, and their lessons and projects that they can think of, it’s a great way to cross-pollinate when you are spending time in the classroom with other teachers.”

Tom’s discussion of individuals as resources is indicative of the fine line that exists between what were identified as “Material”, which here are viewed as “resources” and “Social” which rely upon personal interactions and are discussed further below. Indeed, three of four secondary interview participants reported how collaboration with outside professionals for their own learning and for their students was important to successful integrated STEM teaching and learning.

Returning to the discussion of resources, other secondary, middle school, and elementary participants also indicated resources as an important aspect of their ability to teach content within an integrated STEM framework. Middle school participant Anna indicated that system-wide “restrictions on materials allowed for chemistry experimentation at the middle school level” hampered abilities to engage in a more meaningful range of classroom activities. Anna also strongly supported the acquisition of STEM-specific curricula for teaching content since it was felt that current abilities to teach physical science within an integrated STEM framework were limited by personal lack of experience in ensuring lessons met both content and integrated STEM teaching and learning goals. Anna stated that, “I would really benefit from having some lesson plans that specifically explain to me how to do STEM activities in my classroom but that also include the specific content, the standards, we have to teach.”

This need for curricular support was echoed by Roger who indicated “curriculum” and “lessons” as being important to better science teaching in an integrated STEM framework. Similarly, open-ended responses included “actual coursework and experiences from the real world that are relevant and real to the teacher and students.” Another participant echoed Anna’s concerns about teaching content in an integrated STEM setting, “It can be difficult to teach the core content with inquiry and integrate the STEM concepts.” Others discussed curricular restrictions, likely at the elementary level where as Joseph, Will, and Michelle described, there are a set of math and reading materials that must be used in specific grade levels which then limits the areas available for exploration. Will commented on his attempts to incorporate outside, STEM focused books into his reading collection. “There are lots of good books out there, and I am slowly expanding my library, but we still have to specifically include those books that [the school system] says we have to have students read.”

Similarly, Michelle said that, “One of the challenges for me has been finding ways to include STEM activities in my daily curriculum. We don’t have a lot of time devoted to science anyway and it is made harder by the fact that we are kind of limited in the books and activities we can include.”

Open-ended participants shared this sentiment as evident in the responses including, “not enough time for science in the elementary school setting”, “making sure you incorporate other studies to meet standards”, “development of meaningful activities with budgetary constraints and time issues due to other topics that take priority on state tests”, and “meeting STEM standards while meeting standards and expectations of Common Core. These ideas suggest that well-developed STEM curriculum written to include teaching and content learning expectations would go a long way toward increasing teacher self-efficacy by removing the cognitive demands and emotional distress associated with teaching in new ways. Provision of adequate curricula for STEM science teaching could also move teachers toward the social persuasion and emotional states which Bandura (1994) describes and two of the four sources of influence on individual self-efficacy beliefs.

The importance of curriculum when teaching integrated STEM lessons is evident in research by Bagiati, Yoon, Evangelou, Magana, Kaloustian, and Zhu (2015) who found that globally, open-source engineering curricula are in short supply, and by Guzey, Nyachwaya, Moore, & Roehrig (2014) who found that having established curricular activities improved student achievement, likely due to the unified sense of purpose a curriculum creates. Also, it is possible that an established curriculum removes some of the responsibility from the teacher for ensure all learning activities have a focused goal that will achieve desired learning outcomes.

One of the most striking examples of the importance of resources to integrated STEM teaching and learning was evident in the elementary interviews. System-wide, Will was well-established through reputation as being the most skilled and experienced elementary level, integrated STEM teacher, fully integrating all elementary content into integrated STEM units. Upon interviewing Michelle, it was determined that the materials, especially Flip-Charts created by Will played a central role in Michelle's own confidence to teach integrated STEM. Michelle indicated that the Flip-Charts provided a scaffold for both teacher and students and ensured that teaching and learning goals were not only fluidly presented, but also easily met. She specifically mentioned perception of confidence in ability to carry out lesson plans as being directly associated with provision of curricular materials. She described her experiences, which align to Bandura's (1994) description of vicarious experience and social persuasion as influencing self-efficacy as, "What made the biggest difference to me in deciding to try teaching STEM was the Flip-Charts made by Will. He had everything so well organized, I could clearly follow the lessons and so could the students. I don't know if I could have done it [teach integrated STEM science courses] without having that part already done. Especially not the first time."

Will further maintained the importance of providing free curricular materials to encourage other elementary teachers to attempt science teaching from within an integrated STEM framework specifically noting how attending a summer institute promoting integrated STEM instruction at the elementary level, along with the many free resources that were made available through the conference were the factors that led to his own confidence in abilities to teach elementary content, especially science, as integrated STEM. "That summer PD was really what encouraged me to start teaching STEM. I loved it thought, man, I can do this…I want to do this."

Will also indicated that continued dedication to integrated STEM instruction was a direct result of having had success with teaching in this format, consistent with Bandera's (1997) emphasis on mastery experiences as being the foremost contributor to feelings of self-efficacy to perform specific tasks. As seen in Michelle's comments above stating how important having the support of the Flip-Charts was the first time she attempted to teach science in an integrated STEM framework.

Beyond curricular resources, financial constraints on resources resulted in mixed responses. In the open-ended responses, “money”, “budgetary constraints”, “access to necessary materials”, and “funding” in general were mentioned as factors affected integrated STEM teaching and learning. However, with the exception of Carol who simply stated “financial constraints” as being a concern though she later stated that “there could always be more money to put into more support” as a generalization, as a whole interview participants did not indicate financial constraints as impacting their integrated STEM experiences. However an important point emerged in interview responses from the elementary participants. In final comments on the importance of resources to integrated STEM science instruction, Will and Michelle made an interesting observation in noting they taught in schools where it was easy to send a note home and have parents send in most of the supplies necessary to do integrated STEM projects, and Will expressed concern that this would not be the case for many teachers trying to implement integrated STEM teaching. Will commented, “I am lucky to be in a school where I can just send home a newsletter about the projects we will be doing and the parents will step up and send pretty much everything we need to school with the students.” While Michelle said, “Our parents are really good about sending in almost all of the materials we need for our projects, but I can’t see that being the case for schools in other parts of the county.”

Both Will and Michelle are located in a mid-level to upper middle class, suburban areas where parents tend to be engaged in their students’ education. Will and Michelle were referring to the many schools at the lower end of the socioeconomic spectrum where students frequently come to school without even basic supplies. This implies that there may be some equity issues underlying teacher self-efficacy to teach in an integrated STEM framework, and justifies revision and re-inclusion of the socioeconomic status question. In retrospect, looking at the interview participants' schools it became evident that of the schools with teachers attempting integrated STEM education did not include schools from lower socioeconomic areas of the county and so further research should target teachers in less affluent schools.

One way to possibly parse this information on equity would be to look at differences specifically between grade-level and acquisition of resources, since most secondary-level science materials are not common household materials and are therefore supplied almost entirely through school budgets. While no grade level effects were found in this study that may be due to differences in funding for STEM disciplinary areas as well as for integrated STEM efforts. The researcher's personal experience in the educational system from which most data originated supports the notion that STEM funding for lower SES schools is much higher at the secondary level than for the elementary level where reading and mathematics take precedence. While mathematics is an elementary focus it is independent of the goals of integrated STEM teaching and learning.

Technology. Also within the Resources theme was the category "Technology" which arose at a frequency of 24 incidents in the open-ended responses (18%, N = 130). Technology was interestingly limited to two codes, "Home Access" and "School Access". This can be seen in a comment to the open-ended item in which a participant wrote, "Some students sometimes do not have access to current technologies and only face it [technology] in the classroom. They become better at using technology but are unable to sharpen their skills in their home environments."

It appears that abilities with technology was not an issue with survey participants as a whole though the qualitative data tell a slightly different story. In the evaluation of means it was found that learning new technologies (M = 3.29, SD = .724) and using technology (M = 3.09, SD = .724) both ranked above the average of 2.5 given the 1-4 Likert-type scale. In the discussion of study limitations below, the concerns with the adequacy of this scale will be discussed in detail. Scale limitations also likely explain the fact that “Access Technology” appears as a concern in qualitative data despite participants ranking themselves above average (M = 3.02, SD = .814) on the corresponding survey item. Later analyses examined differences between means based upon the independent variables, gender, and years of teaching experience, and which were supported as having importance influence on teacher perception of self-efficacy to teach science in an integrated STEM framework according to the results of the logistic regression using the GENLIN procedure. As reported it was determined that years of teaching experience was the most important predictor of teacher self-efficacy relevant to the items presented.

As a whole, all teachers interviewed felt they had relatively good access to technology, though as seen above, this was not necessarily the case for their students and may be another indicator of some equity issues as discussed later. Teacher opinions of technology access is evident in comments by Nathan who felt that the technology his school had in place was ample, with the important note that he again mentioned time, the “missing construct” as important to technology use, “It seems like we are pretty well supplied with technology here. We have all the sensors, data collection devices, but maybe not the time to figure out how to use them, because it does take quite a bit of prep to try to figure out *how* it’s going to work first and then how you’re going to present it to the class to get them into it.” Access to technology was also positively described by Tom who said, “I honestly think the technology we have is pretty sufficient.” This differed from the 24 open-ended responses which listed technology as being a significant challenge and included comments such as, “lack of technology”, “having technology available to use in our schools”, “having technology available to use in the classroom,” and “acquiring adequate technology”. Again this hints at equity issues that may be at least partially geographically determined.

In a deviation from technology access is technological ability, which affects self-efficacy. Roger indicated that though he had access to ample technology, he lacked confidence in his ability to use that technology, stating that “I need lots of help with technology. I need lots of support and training.” Nathan’s comments above about finding time to use technology further support the idea that a learning curve for technology exists as he describes preparatory time being essential to using technology effectively. This is consistent with the findings in the model that learning new technologies and using new technologies with students can be important in incorporating the technology aspects of integrated STEM teaching and learning. It can also be speculated that adapting to new teaching situations is included in this part of the model since new teaching situations typically involve teaching in new contexts: in the current classroom this could easily involve implementation of new methods which are highly likely to be technologically enhanced in some way. Furthermore, the idea that professional development targeting learning of new technologies and effectively implementing them in the classroom emerges and is discussed in more detail in the implications section of this research.

Time. A frequently (N=9) invoked concern by teachers in all grade levels emergent from interviews and third most frequently invoked in open-ended responses (N = 17) was an item that was unfortunately not included on the final instrument and has been named “the missing construct”: this was the construct of “time” (13%, N = 130). Every teacher interviewed (N = 9) took the position that it would take more planning time to teach within an integrated STEM framework. Time was a prominent category linked to several re-emergent codes in the open-ended responses including “time to collaborate” “time to plan”, “time in classrooms”, “time to learn new ways of teaching”, “time to work with students on open-ended projects” and for several respondents, time was named by itself as the primary challenge to integrated STEM teaching. One participant simply, but emphatically, listed “TIME TO REACT!” as a response to the biggest challenge facing teachers attempting to teach science in an integrated STEM framework.

Qualitative interview data provide the most insight into this category residing under the “resources” theme. For example, Nathan specifically singled “time” out as one of the primary factors that would improve his integrated STEM teaching, and also mentioned time as a resource itself. He also mentioned having time to learn to use technology and equipment on hand, a concept supported by an open-ended respondent who listed “time to keep up with the changing face of technology” as a challenge in integrated STEM teaching, and another who listed “enough time to learn how to use the equipment and apply it to a classroom setting”.

Similarly, interview participants Roger and Anna mentioned the importance of having time to learn integrated STEM teaching techniques as well as allotted class time to engage in integrated STEM teaching and learning. Anna said, “I really need some time to learn how to teach integrated STEM well. I think there is so much to it and I don’t really have the techniques down at all. Just having time to figure out how to organize it all is a huge barrier.”

All three of the elementary teachers interviewed, Joseph, Will, and Michelle discussed the amount of time allowed for science teaching at the elementary level where the focus is on mathematics and reading to be a major limiting factor affecting their teaching decisions as was discussed alongside the curricular concerns. The idea that dedicated class time for science instruction is an important determinant of integrated STEM teaching efforts is further supported by the fact that high school science teachers, with dedicated, regular content time did not discuss class time in detail, rather focusing more on planning and preparation time. They also mentioned time in terms of planning and collaboration, but not in reference to having ample class time for integrated STEM teaching and learning. As Samuel stated, "As a team, we don't really have time for the degree of collaboration necessary to develop these projects. Professional development system-wide time is never focused on these topics either."

The category "*school-culture*" contained time dedicated to teaching science in an elementary setting as one of its codes. This was included in both the time and the school-culture category since decisions beyond control of an individual teacher's instructional decisions related to time spent on science informs the outcome.

The first three categories, "Resources", "Technology" specifically access to technology, and "Time" created the theme "Resources" and can be associated with the quantitative emergence of Factor 3, "Material" as partially explaining the final accepted structural model. Resources and Technology were both included in study, but future instrument development should include items directed at measuring the effects of time on teacher self-efficacy to teach science in an integrated STEM framework, as discussed in the implications and limitations below.

Personal

The factor named "Personal" had a total of nine items loading on it in the final accepted model. This factor was so named reflective of the fact that the items loading on it all relate to self-efficacy regarding internal abilities, or those abilities not influenced by external sources including content knowledge, understanding of integrated STEM teaching and learning, confidence in pedagogical strengths, and experiences that support teaching and according to Bandura (1997) includes both mastery and vicarious experiences.

Experience. In the semi-structured interviews, an important qualitative category to emerge was “experience” which was included in the instrument in formats including the pedagogical item kept in the final model measuring confidence in ability to use teaching experience to teach science effectively from within an integrated STEM framework. Responses from participants suggest this is an important item since self-doubt about ability to teach non-science content in a meaningful way arose multiple times across interviews and in open-ended responses. A specific demographic item intended to measure experience was included after the initial pilot interviews supported inclusion of experience measures in the instrument. In the interviews conducted to validate the 30-item instrument, the two teachers with less than two-year’s teaching experience both mentioned being a new teacher and having to learn some of the pedagogical aspects of teaching. Nathan described his journey to become a teacher as being at least partially tied to the development of pedagogy, “…bringing people who are highly qualified in their business outside into a school and training them in pedagogy and everything, and classroom management, being able to put all that together and make it work, that’s been the biggest challenge really.” While Sarah stated that, “What I don’t have a lot of yet, being an inexperienced teacher, is knowing what kind of labs we can do, in the classroom. What are the typical high school Chemistry labs, and I need more experience with the teaching aspects of it, with teaching Chemistry and how to tie the other content in.”

The ability to turn focus away from the daily activities of teaching and toward the teaching of content itself supports the significant finding from the regression analysis that being a teacher with between one and two-year's experience is a predictor of how participants will view their self-efficacy to teach integrated STEM relative to specific attributes embodied in the instrument items.

Supporting qualitative interview data include responses from two novice secondary teachers (< 2 years teaching experience) who both mentioned being a new teacher and having to learn some of the pedagogical aspects of teaching was made easier due to past professional experiences. Nathan mentioned how the transition from a STEM career (environmental consulting) to teaching integrated STEM was made easier because of the fact that his day to day job responsibilities required the very skillsets he was attempting to impart to his students. Carol described her significant research background as being integral to her abilities to teach her own students to engage in research activities.

Even the more experienced secondary teachers still cited their professional experience as being central to their ability to successfully teach science in a STEM framework, with Samuel detailing his experiences over 30-plus years as an electrical engineer as helping him to understand necessary abilities students must have if they are to compete with other professionals in a STEM career. He noted especially that knowledge of what students need to know and be able to do in those careers, coupled with his confidence in his subject matter was directly a result of his professional experiences. And Tom explained how his background in physics coupled with his training in mathematics bolstered his confidence with his STEM content teaching, "I was trained as a math teacher, but my background is in physics, that's my comfort area, so I feel really confident about my content there, too. I guess because of that it [teaching integrated STEM] just comes naturally to me."

Open-ended responses discussing experience included comments such as “lack of background knowledge outside of a specialty field”, “lack of understanding of basic STEM implementation”, “I lack the engineering and technology knowledge to feel confident in my abilities to teach STEM effectively”, and “for experienced teachers who have become specialized in their content, large-scale support would be necessary in terms of STEM content knowledge and methodology.” The last statement especially suggests an awareness on the part of teachers that past experiences may be insufficient to negotiate a more complex, novel teaching situation.

Research supports the importance of professional experience and STEM teaching, especially in urban schools where staffing in mathematics and science is challenging (Stoddart & Floden, 1995). The idea that having a degree in a subject equates to content knowledge (Bowen, 2014) and that content connections between STEM disciplines such as math and science may be easier for those with professional experience (Chambers, 2002; Marinell, 2008 in Bowen, 2014) have been proposed. However, whether this content knowledge translates into pedagogy is questionable given current STEM studies such as that by Bowen (2014) who found that career experience did not always translate into instruction, especially when perceptions of student abilities were involved.

While barely evident in the category “Real-World Experience” which only had two codes falling within the category, the feeling that experience is important to perceived self-efficacy to teach science in an integrated STEM framework is further supported in the significant regression analysis finding that being a teacher with between one and two-year’s experience is a predictor of how participants will view their self-efficacy to teach integrated STEM relative to specific attributes embodied in the instrument items. Furthermore, it suggests there is a strong aspect of self-efficacy that arises from having had professional experiences over a long period of time (years) within a career field of the discipline being taught. This is interesting from the anecdotal perspective of the researcher who determined that secondary schools with a STEM-based mission tend to have large applicant pools for positions, and from those pools, though most applicants are from traditional, education-degree tracks, the schools migrate towards applicants with career experience. As a result of the statistical findings, creating items specifically targeting measures of non-education related experiences may provide important insights and potentially new factors explaining the final structural model that translates into the SETIS instrument.

Also within "experience" was a subcategory named "career experience" that seemed important in interviews though it did not emerge in open-ended responses. This overlapped into "Social" aspects of self-efficacy. This is likely strongly related to the same mindset that led to statements about professional experience as a factor important to one's confidence in STEM teaching abilities. All secondary and one of two middle school teachers mentioned the importance of exposing students to professionals from STEM careers. Nathan, in discussing resources he would like to add to his STEM teaching noted that felt job shadowing programs exposing students to actual careers was an important experience for students: "Really what I would probably do is plug each student into a shadowing program where they would go and watch someone who knows what they're doing."

Carol mentioned the importance of access to professionals, saying, "I think our students would really benefit from access to professionals who actually work in STEM careers doing the types of jobs, using the skills we are trying to teach. Getting to see it first-hand would be a great learning experience."

Samuel expressed the belief that exposure to professionals was very important. In describing internship opportunities for high-school seniors said, “I think one of the most valuable things we offer as a school is our internship for those students that qualify. This is really the best way to teach them about STEM, to get them out there with people who do those jobs every day - that is powerful”

Tom supported bringing professionals into the schools to expose students to STEM careers. “I like to bring professionals from STEM careers into the classroom in order to bring a certain authenticity to the mindsets we are trying to create. I think the more students are exposed to real-world scenarios the more likely they are to have a sense of ownership for their own learning.”

Anna remarked that, “My own shortcomings in terms of my knowledge of STEM careers, since I have only actually been a teacher and not actually worked in a STEM career, can be at least partly overcome by bringing guest speakers into the classroom to talk about what they do with students. We don’t get to do this too often, really I just don’t get around to organizing things, but it is really important to establishing relevance with the content. It’s a great learning experience.”

This opinion supports the idea that teachers feel like real-world knowledge and experiences play an important role in the whole STEM teaching and learning paradigm. Future iterations of the instrument should include efforts to include items directed at measuring teacher self-efficacy from an experiential standpoint with direct consideration of professional experiences at the “personal” and “social” levels. “Personal” experience would include teachers own experiences that they feel have better prepared them for integrated STEM teaching and learning. “Social” experience would include bringing in career-field professionals as resources from the outside and "Social" experiences as guiding students in their learning and navigation of self- and group-directed STEM projects and is discussed in the next section looking at "Social".

Pedagogical abilities. Expanding upon the concept of experience is the proposed third category, which actually seems to be best organized under experience, and that was the category named "classroom management". This can be housed under experience since ability to manage a classroom certainly requires a degree of practice in order to achieve mastery. In looking at this category, it must be noted that it was entirely confined to elementary teacher responses in the semi-structured interviews and one novice secondary science teacher, Nathan as seen in his statements previously discussed. All of the elementary teachers and the single high school teacher interviewed suggested that classroom management was one of the primary abilities that teachers had to possess in order to successfully engage in integrated STEM teaching and learning. The primary difference between elementary and the secondary responses was that the secondary science teacher described classroom management as a skill to be acquired and implemented for disciplinary reasons as seen by Nathan's comment, "I think STEM works better when you have smaller groups really, you know, focusing a lot better and helping them find direction as opposed to herding cats."

The elementary teachers focused their description on classroom management not as discipline, but rather as the need to assist students in navigating complex tasks in order to achieve learning goals. They described the energy and disorganization that accompanies "projects" in elementary grades to be a major area in which teachers had to possess strong classroom pedagogy if projects were to succeed. Will said, "One of the most important aspects of STEM teaching is to have everything really well organized since the kids can be all over the place with their ideas and energy. Keeping them focused and having clear objectives for them helps to overcome some of that."

Similarly, Michelle provided statements supporting organization as a form of classroom management. She stated, "With elementary students, they can have a hard time with open-ended projects. It is really crucial that, for myself, I am well-prepared ahead of time so I don't have to be thinking about what we are doing next and instead focus on helping the kids stay on task. Having the materials ready to go, having everybody on the same page at the start of the project and clear about what we are doing, that's where the Flip-Charts are so helpful, too."

Open-ended responses included a category named "Pedagogical Knowledge and Skills" but classroom management did not specifically appear as a code in this category. It may be that the integrated STEM specificity of the question directed responses more toward the codes that did appear including "discipline-specific pedagogies", "pedagogical knowledge for integrating classes", "questioning skills", and "eliciting critical thinking". As an ability, beliefs about pedagogical ability resides strongly within the construct of self-efficacy since it describes confidence in ability to accomplish an action/task such as a specific teaching task (Bandura, 1994).

The other aspect of pedagogical knowledge that appeared in the open-ended questions but was absent in all but the middle school interviews was pedagogical content knowledge, primarily for non-science disciplines. In open-ended responses, participants mentioned doubts about their content knowledge on 17 different occasions with "engineering knowledge", "technology knowledge", "knowledge outside of disciplinary area" and "knowledge for how to teach content within an integrated STEM framework" as being the most common codes appearing. This is unsurprising given the fact that most teachers have very limited experience outside of their content areas even though content learning remains paramount in teacher preparation programs (Wilson, 2011). With the number of disciplines needing to be integrated it is no wonder that teachers may feel uncertain of their content abilities. Indeed, Sanders (2009) discusses how the magnitude of knowledge required to teach any one of the STEM disciplines alone is daunting, and he expresses doubt that teacher preparation programs and professional development could sufficiently remedy this problem. Sanders (2009) goes on to support integrative STEM teacher preparation efforts in which cross-disciplinary collaboration is used to for further developing knowledge and understanding (p. 22). Further, designated curricular materials as discussed in the section on resources within "Material" can help teachers implement STEM disciplinary content more effectively, as indicated in an analysis by Brophy, Klein, Portsmore, and Rogers (2008) who explored instructional models for implementing engineering education in P-12 classrooms. The programs analyzed were more successful when curricular materials and ongoing professional support were available for teachers, though they did report the need for greater insight and understanding of teacher pedagogical content knowledge acquisition to ensure teacher efficacy. Similarly, Stricker (2011), in a study also examining teaching of engineering concepts in science indicates the importance of curricula that feature "powerful learning activities that are underpinned by the teacher's articulated understanding of the concepts they were built to teach" (p. 95). Beyond that fact that the science course was called "Advanced Competitive Science" and is therefore not a core, tested class, it is difficult to imagine that even at the secondary level there will be many teachers who feel they possess the subject matter knowledge outside of their core content area sufficient to effectively enact deep learning of content equally across STEM disciplines.

Tom made comments as discussed above about how his integrative abilities were enhanced by the fact that he was strong in both mathematics and science, specifically physics which likely strengthens his engineering self-efficacy beliefs as well. Samuel also came from a background in engineering and is certified in both math and science (physics) as well as having extensive computer programming skills. His statements are supportive of his pedagogical content knowledge as seen in his response to an interview question asking about integrated STEM teaching strengths. Tom stated, “I probably have it easier than most since I have a strong background in all of the STEM disciplines. Unless I am teaching a math course specifically integrating content is easy because it is necessary. Programming usually has an engineering goal: you are trying to engineer technology to do something specifically. Math is the language for doing that. Physics studies technology and explains engineering design. Easy.”

The fact that middle school interview participants expressed the most uncertainty in terms of pedagogical content knowledge likely stems from the fact that secondary teachers tend to be more content-trained than middle-school teachers and elementary teachers simply don’t require the depth of content knowledge to teach at their academic grade levels. For example, Roger in talking about his content knowledge said, “I would need brushing up on all of it. I feel like content-wise I don’t feel uncomfortable with the content, but I don’t really know it that well. I really don’t think I know well how to teach it all at once.”

Anna had similar beliefs about her STEM teaching abilities as seen in her statement, “I am really, I think, limited in my knowledge of any of the disciplines to any depth. I have certain content that I teach and ways that I know to teach it and trying to change up, to teach it more integrated, would require that I have to learn new ways to teach…new material…but also new ways to teach.

Confidence in pedagogical content knowledge has been reported to be variable for secondary versus middle school with content exposure being a large variable. Kuenzi, 2006, reports that while most secondary math and science teachers are certified in their content area (99.7%), 51.5% of middle school teachers who taught math and 40% who taught science did not possess a degree of any sort in those areas (p. 9) which could certainly lead to feelings of insecurity in terms of content teaching. This may be an area where significant professional development could contribute to increases in integrated STEM teaching. As stated by Nadelson, Seifert, Moll & Coats (2012), "if teachers are discontent with their pedagogy, the will not feel comfortable teaching the content" (p. 70) which they then equate with teacher inefficacy.

The other factor likely contributing to the situation wherein pedagogical content knowledge was seen as an area of concern more so on the open-ended responses than in interviews was that the interviewed teachers were actually already teaching integrated STEM and so had some experience to improve their self-efficacy. Earlier in this research the importance of experience to teacher self-efficacy to teach science in an integrated STEM framework was discussed. Open-ended comments about pedagogical content knowledge and content knowledge in general included "my engineering knowledge is probably less than what it could be", "lack of background knowledge outside of a specialty field", "inadequate content knowledge", "having the content knowledge necessary", "that science doesn't get lost in the engineering and technology", "teacher content knowledge", and "content knowledge needs to be strengthened among elementary teachers." Open-ended responses were not directly listed as pedagogical content knowledge, but the pedagogy of teaching content is directly related to content knowledge itself and so these comments were included.

Understanding integrated STEM. Aligning with this pedagogical knowledge and skills was the category "Understanding Integrated STEM" which was important in the open-ended responses with eleven associated codes though less so in the interviews, which again is likely due to the fact that interview participants were chosen because it was determined that they had some level of knowledge about integrated STEM teaching and learning. Participants described not really understanding what integrated STEM was as a primary challenge for teachers considering implementing integrated STEM in their science classes. Certainly before pedagogy for teaching integrated STEM can develop, an understanding of what is meant by integrated STEM teaching and learning must exist.

Some of the statements in the open-ended responses indicating that understanding integrated STEM included, "STEM instruction has not been discussed with science teachers at any length", "more professional development for teachers that haven't been certified to teach STEM courses", "opportunity to talk to other teachers who are integrating STEM in their science courses", "knowing what it is", "understanding of basic STEM implementation", "lack of confidence in STEM knowledge", "lack of knowledge about the meaning of STEM by administrators", "lack of awareness of what STEM is" and "I am not familiar with the expectations of an integrated STEM curriculum.

In a lengthier response, one participant furthered the unfamiliarity with integrated STEM teaching and learning as anticipated and discussed in the literature review. Specifically, this participant wrote, "The biggest challenge is that teachers who haven't had STEM training don't understand what they are supposed to do in order to incorporate it into their curriculum." This not only suggests that an understanding of integrated STEM is in deficit, but that professional development and curricular resources will play a central role in the future of integrated STEM teacher self-efficacy.

Social

The third factor explaining the structure of teacher self-efficacy to teach science through integrated STEM was "Social" and is distinguished by the fact that it contains aspects of self-efficacy that involve interactions with others including students, other teachers, administrators, school-systems, and even individuals at the policy-making level. In terms of self-efficacy, though some items such as assessment, questioning, and collaboration may rely somewhat on self-abilities, there is also a component that relies upon the willingness and abilities of others to engage in the activity and interact as a full, dedicated participant and falls under the influential category of "social persuasion" as described by Bandura (1997). This is supported by research from Enochs, Scharmann, and Riggs (1995) who found that elementary teachers' perceived self-efficacy to teach science was at least partially explained by whether they expected their students to be "responsible, cooperative participants in the classroom" (p. 71). More recent research by Caprara, Barbaranelli, Steca, and Malone (2006) also linked teacher self-efficacy to student achievement and motivation. The open-ended categories emerging that reflected this attenuation to others included "Thinking Style", "Collaboration", "Professional Development", "Support", "School Culture", and "Student Apathy", the latter of which is probably actually better situated within the category "Thinking Style".

Thinking style. Using professional, experiential knowledge mentioned in the previous "Personal" discussion is related to the next category which was what teachers felt students needed to know and do in order to be truly participating in integrated STEM science learning. As mentioned in the results section above, interview responses to questions on student knowledge, challenges, and content delivery, some specific codes repeatedly emerged related to "habits of mind", "STEM habits", "skillsets", "mastery", "ownership", and "facilitate learning". Before discussing these however, it should be reiterated that though thinking style was placed in the "Social" locus, there are very strong pedagogical factors that inarguably contribute to self-efficacy in this area. The decision to place "Thinking Style" in "Social" was because it requires a certain willingness on the part of participants and therefore is not entirely under the teacher's control. It will be seen with other categories in "Social" that this same situation exists where pedagogical knowledge and skills cannot be ignored as playing a contributing role. Specific characteristics of thinking style as defining integrated STEM science contexts can be seen primarily in the interviews. One instance was put forward by Nathan who, in describing integrated STEM, used the phrase, "a way to think", and Tom who, responding to the same question, described integrated STEM as a "kind of as a mindset", with a goal more aligned with applying practices across disciplines. Tom went on to describe how his school actually has a dedicated list of "STEM Habits" to which students are expected to adhere.

This was closely related to the "skillsets", "mastery", "ownership" and "facilitate learning" that were repeatedly invoked across the interviews. In fact, STEM habits actually seem to be a type of skillset, or mind tools that can be used to navigate the course of a problem-solving or design challenge and rely heavily upon principles of self-directed learning. For example, Anna, in expressing concern about her abilities to teach integrated STEM using her current knowledge base, said that she felt "there are certain skillsets students have to have in order to successfully pull off STEM projects" and that she would need training to learn to impart these to students.

And again, Nathan, in response to questions about the types of attitudes he holds toward teaching science in an integrated STEM framework spoke about his perceived understanding of what students needed to focus on to succeed in integrated STEM environments supporting the idea that there are certain mindsets that students need to possess to have positive outcomes. Nathan described his understanding as, “In your science classes you should write about things, be able to do, produce a product, you know, using all the skills you have. To emphasize, science technology, engineering, and math: it’s a way of thinking. There are several things we need to do, say dissemination of information, how you use that information, synthesize it, pulling it all together.”

Carol described her experiences with facilitating student mindsets within integrated STEM contexts as being less demanding in terms of content knowledge with a focus instead upon teaching students to be self-directed learners who know how to do research and find their own answers as well learning through their own experiences. As Carol expressed, “Students are supposed to guide themselves, take on their own interests, grow their own conclusions, they’re not going to teach themselves by just reading a book.”

Tom also discussed student learning in an integrated STEM context as being different than traditional science classes, as with Carol explaining that students need to learn what they need on their own, from each other, and from their own research, specifically describing, “learning by doing” as opposed to learning content directly from the teacher.

It could be said that “Doing STEM” may be something of its own category. Interview participants, especially middle school participants, indicated that they felt there were certain things students needed to be doing in order to be participating in integrated STEM learning. For example, Roger described integrated STEM teaching and learning as involving projects, hands-on activities, and technology. Anna,expressed that there were specific types of STEM activities when she expressed doubt in her own abilities to know "how to do the *things* necessary to teach science *that way*."

At the elementary and middle school level, it was discussed that one of the challenges was getting students used to the type of thinking processes necessary to be able to follow through with a project from start to finish. Will and Anna both noted the necessity for students in integrated STEM environments to develop learning styles that are more flexible in terms of being accepting of open-endedness of projects and problems and the common lack of a defined "answer" to a problem or challenge. Will furthered this sentiment as he described how "Sometimes it is difficult to get students to accept new learning styles, especially as they get older and are more set in their ways I think it is definitely easier with the younger ones, to get them started off that way from the outset."

The premise that STEM education should be started early in elementary education is supported by Bagiati, Yoon, Evangelou, Magana, Kaloutain, and Zhu (2015) who looked at global trends in engineering resources for teachers. They note the need for increased teacher access to open-source resources specifically in the form of curricular offerings given that, while single lessons and activities were easy to access on the internet, access to meaningful, developed curricula were few. Shortage of appropriate resources is a barrier to teachers who may be seeking ideas for instruction outside of their content specialties or existing curricular provisions from within their districts.

While STEM habits of mind and STEM habits were mentioned across grade levels in the interviews, they were interestingly only vaguely indicated in the open-ended responses. Open-ended responses supporting this concern were included in the category named "Thinking Style" and involved references to getting students to use critical thinking skills, and “student buy-in”. One responded described the problem in the response to challenges, “getting teachers to use open-ended questions in order to get students to use their critical thinking skills instead of just memorizing facts.” Another teacher eloquently discussed the different thinking style and mindsets associated with integrated STEM teaching and learning, “One of the biggest challenges at my school would be the focus on standardized testing, and our school’s performance on those tests. The tests themselves are based on very discrete skills that do not require integrated thinking, so it would be hard to convince the administration that a different method of teaching would benefit the students. It would have to be a whole school culture change.”

Collaboration. The categories “Collaboration” and “Professional Development” arose during the interviews and suggest that some of the items in the survey that showed complexity on the rotated factor matrix during the exploratory factor analysis may need to be revisited and included in later iterations of the instrument since both phrases appeared. Collaboration emerged in two places; with time and with learning. Teachers talked about collaboration and the importance of it. Tom described his experiences with collaboration as through co-teaching and noted how co-teachers have always been good resources for content ideas, but also for STEM modeling, teaching methods, and their lessons and projects describing co-teaching as a form of “cross-pollination” This was seen with Will who mentioned how the sharing of his lessons with the two other teachers in his grade level had encouraged them to try including some STEM lessons in their own classrooms. Collaboration in this form is very similar to professional development as evidence in elaboration by both Michelle and Will. Will described his experiences as having first become interested in teaching science from within an integrated STEM framework after attending a multi-day workshop. Michelle became interested after attending a professional development session led by Will after he had experimented with, and come to greatly value this form of teaching for his second grade classroom. Both Michelle and Will discussed the importance of shared resources. Will, as described previously had created some Flip-Charts, which he described as being an easy way to guide a STEM lesson with students, and Michelle mentioned these same Flip-Charts as making her believe she could actually pull off a STEM science lesson. This expression of belief in ability fits precisely within the framework of self-efficacy theory and the realization that self-efficacy is very much a socially-developed characteristic. (Bandura, 1994).

Collaboration was also mentioned with reference to time, with time being, one of the most frequently documented "perceived challenges" for teaching science within an integrated STEM framework (N=17). Time and again in the open-ended response, "time" and "time to collaborate" were typed into the response fields. Teachers felt that time to collaborate would be a necessary part of ability to teach in an integrated STEM framework as evident in comments by Nathan and Tom who indicated the importance of mentoring and co-teaching on their own development as integrated STEM teachers

Professional development. Professional Development was the other category that was removed for complexity. In the most telling example of the importance of professional development, both elementary teachers indicated, as evident in the paragraphs preceding this one that the whole reason they adopted integrated STEM teaching and learning for their science courses was as a result of a professional development training they had attended. Also, middle school teacher, Anna, mentioned that she would absolutely need training in the form of professional development if she was to try and adopt a STEM approach to science teaching.

In open-ended responses, professional development earned a category designation with nine codes being associated with it. Most professional development responses were focused on the need to specifically be trained in integrated STEM content teaching and implementation techniques. One respondent wrote, “I would definitely need professional development to improve my engineering knowledge”, while and indicated that in personal experience STEM instruction had not been discussed at any length with science teachers. Still another respondent wrote that “teachers not certified in STEM teaching would require extensive professional development”. Other responses included “supportive training”, “content training in other disciplines” and “providing more professional development” simply listed alone as a need.

Brophy et al., (2008) discuss how pedagogical content knowledge must be included when engineering and science contexts, which can be open-ended and complicated for teachers to negotiate can be strengthened through “well-designed and supportive ongoing professional development” (p. 383).

Support. “Support” emerged as a category in the open-ended responses as well as in interviews and so should be considered for future item development. Support included administrative, political, and parental associations as seen in the open-ended responses and so was distinguished from support in the form of professional development. In the interviews, Michelle and Will mentioned the importance of support in the forms of materials from parents of their students as being an important factor in their successful integrated STEM teaching. Will also mentioned how his administrative staff was extremely supportive in giving him the leeway to pursue integrated STEM projects within his elementary classroom, saying “For me, having an administration who is willing to let me try new things as long as I am getting in all the other required curriculum is really important. You got to have administration behind you.”

A similar finding occurred with Carol who felt "having a supportive administrative staff is an important part of the collaborative process. In order for ample collaborative opportunities to occur it is important to have an administrative staff who values collaboration and provides actual time allotted for collaboration." Tom stated that he "would like to see greater administrative involvement in STEM courses", noting that "evaluation during STEM teaching and learning would help me to better self-evaluate and improve my craft. I think it is important to have that feedback from others who are looking at your practice your craft. Maybe see what you don't see in your teaching."

Political implications of support were evident in the elementary responses both in interviews and in open-ended responses, and this was seen in two forms. First the elementary teachers all noted in their interviews that policy regarding class time spent on science teaching was limited by system-wide and state-wide mandates. Furthermore, Will, as previously discussed mentioned restrictions on reading materials that could be used to support integrated learning due to designated reading materials that seldom had a scientific theme related to what was being studied in class. Reading material limitations were seen to directly confound attempts to better integrated subject areas.

The other incidence in which political decisions were seen to influence classroom decisions to teach science in an integrated STEM framework was discussed by all of the interview participants and arose several times in the open-ended responses: the testing decisions imposed by states and school systems. Teachers indicated that they worried about being able to introduce all the necessary content standards while also attempting to integrate other subjects, especially given pressures such as Common Core State Standards and TCAP testing. Some of the comments included, "meeting STEM standards while meeting standards and expectations of common core", "tying STEM into the content needed for evaluations and state assessments", "focus on standardized testing and the importance of school performance on those tests", and "current focus on state standards" among others.

Implications

Research Implications

Addressing the first research questions: (1) Can an instrument with acceptable validity and reliability be developed for the measurement of science teachers' self-efficacy to teach science within an integrated STEM framework? and (2) What are the constructs that define teacher self-efficacy to teach science within an integrated STEM framework?: this research seems to have successfully developed a valid, prototype of an instrument with suitable reliability to accept the findings as acceptable measures of the self-efficacy goals outlined. However, it should be noted that this research also raises several future research questions for consideration prior to using this instrument to gauge teachers' expected ability to find success in an integrated STEM science classroom.

First, the demographics of the sample population should be, if at all possible, more representative of minority groups, which in K-12 science education would include non-whites and to some extent also males. As was seen in this research, only 14 respondents of 194 indicated they belonged to non-white ethnic groups, and 47 of 194 were male. One way to counteract this might be to specifically target the survey to school districts with high populations of African-Americans, Hispanics, and those of the broad diversity of Asian descents.

In concert with this demographic expansion, and aligned with the finding that socio-economic disparities in integrated STEM settings may exist, a related demographic question in a user-friendly format should be included. This question should have the express goal of creating a more lucid and representative picture of how and where integrated STEM teaching and learning occurs, and more importantly, how do equity issues affect teacher self-efficacy? It can be predicted that many “Social” items might be related to these predictors as well as “Material” items in places where access to technology and materials reflect socioeconomic disadvantage, mindful of the importance placed on parent-supplied materials by elementary teachers.

The three-factor model produced again had sound reliability with “Social”” at $\alpha = .917$, “Personal” at $\alpha = .918$, and “Material” at $\alpha = .878$ (Table 13). Still, the amount of variance explained hovered around a disappointing 0.63% leaving the research dissatisfied with the final model. Given two factors that loaded on “Social” but were removed for complexity, these being “Collaboration” and “Professional Development” and the fact that both of these were shown to be important in the interview responses, it is likely some meaningful attributes of self-efficacy reside within their loci. Future research should review aspects of collaboration and professional development most valued by teachers specifically science teachers in integrated STEM teaching frameworks, and subsequently develop some survey items intended to measure these attributes to determine if they are useful to the model in terms of explaining the remaining 37% of the variance.

Looking at professional development offerings, in incidences intended to provide opportunities to improve integrated STEM teaching, it should be noted that for years most professional development has been viewed as ineffective (Guskey, 2002). Heibert (1995) specifically tied high quality professional development to opportunities to collaboration, suggesting the two constructs may be intrinsically linked. Collaboration was found to be important to undergraduate education students attempting learn engineering content (Crumbaugh, Vellom, Kline, and Tsang (2004), but despite collaboration was hampered by differences in “underlying assumptions, language patterns, and goals” (p. 17) – in other words, the jargon associated with the content was a barrier itself. This finding was echoed by Hora (2007) who found sense of meaning to interfere with effective collaboration between STEM faculty and education faculty. However, professional development itself, which usually involves collaborative efforts, has been found to be valuable. Asghar, Ellington, Rice, Johnson, and Prime (2012) found that university-based professional development programs provides limited support to teachers, in their research specifically secondary science and math teachers, in navigating the complexities of problem-based learning in STEM approaches. They found that many factors including testing obligations hindered teacher implementation of STEM lessons and beyond recommending more professional development opportunities, also indicated that this was an area warranting more investigation. This further justifies the need for dedicated efforts to explore collaboration and professional development as aspects of teacher self-efficacy to teach science in an integrated STEM framework since it seems that a multidimensional layer of complexity may surround these constructs and therefore may have contributed to the problematic indication of complexity revealed in the factor analysis. Moreover, given that self-efficacy plays such an important role in teacher willingness to persevere in the face of challenges and that self-efficacy can be a vicarious attribute learned through collaborative efforts, after resolving the collaboration and professional development conundrum, this instrument in its final configuration may provide some guidance into the specific needs of teachers and thus direct future professional development and collaborative efforts in that vein. Finally, based upon teacher interviews and open-ended responses, it appears the construct “time” also is very important explaining teacher self-efficacy to teach science in an integrated STEM framework. The original 30-item survey failed to include questions on time which is obviously an oversight given the importance of time in these interviews. Likely, time is viewed as a resource that would fall within the "Social" if it did not develop into its own factor.

Practical Implications

From a practical perspective, this research provides some important implications for administrators, teachers, and teacher-educators. First, it does appear that the SETIS Instrument does have the capacity to measure teacher self-efficacy to teach science in an integrated STEM framework. As discussed it will be necessary to revise the instrument to provide a more discriminating scale. Once instrument development has been finalized, considering the value of improving self-efficacy in order to develop teachers with strong beliefs about personal abilities, the SETIS Instrument could be used to target professional development specifically toward creating personalized opportunities. These opportunities for professional development, whether mastery experiences, vicarious experiences, social persuasion, or emotional state, could be specifically directed toward improving self-efficacy in areas showing low self-efficacy scores. Many teachers expressed the need for additional professional development, specifically citing professional development in content areas with which they were unfamiliar. There are opportunities for professional development sessions led by practicing teachers to meet Bandura's (1994) category of vicarious experience, which seems especially important given Michelle's strong response to the professional development session taught by Will. In turn, Will also had strong comments about how important thinking "I can do this, I want to do this in my classroom" after having attended an integrated STEM science teaching weeklong professional development opportunity. Bandura (1994) discusses how important observing others at levels that seem attainable can be. This has been supported by research on teacher education candidates in agricultural science who had strong positive self-efficacy improvements in the fact of vicarious experiences to which they could relate in terms of their own abilities (Wolf, Foster & Birkenholz, 2010). However, professional development aimed at complex integration of STEM disciplines cannot be piecemeal and sporadic but rather needs to be of appropriate duration to lead to development of confidence in skills necessary for successful integration. Brinkerhoff (2006) cites Cuban, Kirkpatrick, & Peck (2001) as noting that most "professional development is not specific to teachers' needs" (p. 37). Further, Brinkerhoff's (2006) own research found that lengthier professional development offerings geared toward a single objective, in his case technology integration, and repeated for reinforcement is one of the best ways to improve self-efficacy for his research subjects.

The idea that STEM integration would require specific professional development also has practical implications for administrators with school-wide integrated STEM teaching and learning goals. The SETIS Instrument, once finalized, could be used as a valuable tool for evaluating teaching and making those professional development decisions that best support teachers and their self-efficacy needs rather than scheduling school-wide in-service opportunities that focus on general skills. For example, for teachers with lower self-efficacy in content, professional development should focus on content knowledge gains while teachers with lower self-efficacy in integration pedagogy should have a discerned focus in that direction. Similarly, in teacher education programs, which have the luxury of being taught over a longer duration as promoted by Brinkerhoff (2006) are naturally venues for the types of specialized learning opportunities in response to needs that may be identified as a result of using the SETIS Instrument.

Additionally, there are implications relative to the emergent theme suggesting that collaborative opportunities are very important to teachers. Reflecting on Bandura's (1997) indications of the central role of social interactions, as with vicarious experiences and social persuasion, it seems ensuring teachers have access to that time to collaborate and plan together can be predicted to be important to continued teaching gains and overall confidence in ability. By further exploring the concept of "time" which was so often tied to "time for collaboration", it might be that collaboration itself emerges as a distinct construct in the three factor outcome.

Limitations

An unavoidable limitation of this research was that there was no good method of obtaining a random sample within the time allotted to collect data. As expected, the data were both gender and ethnicity biased to the point that ethnicity effects could not be measured. Additionally, some of the participants were self-selecting in that they were attendees at a state science conference and/or members of state science associations. For this reason, it could be the case that the results are skewed in one direction or another in terms of self-efficacy since those who engage in societies and conferences may have different characteristics than those who do not engage in societies and conferences. For future research it would be useful, if not impractical, to develop a sample that was equally distributed in terms of gender and ethnicity by repeating the survey delivery until an acceptable number of responses from each demographic category was obtained.

A second limitation was in the small Likert scale range (1-4) which may not have allowed for adequate distinction between responses. Self-efficacy scales are strongest when they have participants rank themselves between 0-100 on their confidence in ability to perform an action or task specified by the item (Bandura, 1994). This research originally used a fill-in field using this scale, followed by a 0-10 scale which Bandura (1994) also indicates as appropriate as a next-best measure. The reason for using 1-4 was to avoid confusing participants who are used to the typical 1-5 Likert-type scale with 0 representing “strongly disagree” and 5 representing “strongly agree”. What resulted was a situation where there was only a .45 range between the means of all of the items in the survey. This seriously compromises any conclusions about the final model. It may be that a participant ranking themselves “very confident” on the 1-4 scale may be closer to being a 75% than 100% confident, which is a substantial difference.

Another benefit of the 0-100 Likert-type scale is that it would have put the responses into the form of a continuous variable which would have allowed for some stronger statistical tests such as ANOVA and MANCOVA to be applied to the dataset. The post-hoc tests associated with these analyses allow for simple identification of where and what the differences between predictors and dependent variables actually are.

Producing yet another limitation, it was actually recognized post-study that of the teachers surveyed, five were teaching at mid-level to upper middle class neighborhood schools where resources are easier to obtain, while the other four were from magnet schools and so had a range of students from all socioeconomic categories. As mentioned by one interview participant, the parents of her students are very generous in donating to classroom needs. This leads into the next feature of mid-to upper SES schools: the parents and students tend to have higher expectations for themselves and engage more in their learning. Future research should include attention to including a specific range of socioeconomic categories when identifying interview participants.

Finally and importantly is what I will call “the missing factor.” Based upon the results of the survey and especially considering the confirmatory interviews, it appears that one of the most important factors as indicated by teachers in considering implementation of an integrated STEM framework from which to teach their science content, is time. Repeatedly in each interview and populating the open-ended questions field was concern about ability to find time to teach science in this less content oriented, but more complex manner. It was already mentioned above that "time to collaborate" was a factor of interest, and it is likely that time may be oriented to other specific attributes such as "time to plan", "time to assess", "time to work with individual students", or other related items. It may be wise to make an attempt to analyze the role of time in science teacher self-efficacy to teach their content area with an integrated STEM framework.

Given these implications and limitations, in concert with the finding that the variance was lower than ideal and that there were some items that emerged in the qualitative analysis that suggest there may be some other items that would load on the factors if included or reworded suggests that there is work yet to be done with the SETIS instrument. Future development should include items measuring time influences on self-efficacy as well as further attention to the effects of professional experience, collaboration, and professional development opportunities. Additionally, a more sensitive scale should be used to ensure adequate distinction between responses. Nonetheless, it can be said that the current SETIS Instrument is an acceptable instrument to develop a fundamental measurement of teacher self-efficacy to teach science in an integrated STEM framework.

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APPENDICES

APPENDIX A

Semi-Structured Interview Questions

1. What does the concept "STEM" mean to you?
2. What does integrated STEM teaching and learning mean to you?
3. What do you think are the primary goals of integrated STEM teaching and learning?
4. What type of attitudes do you hold towards teaching within an integrated STEM framework?
5. What are the demands, in the form of knowledge and skills, for teaching science within an integrated STEM framework?
6. How prepared do you feel to teach within an integrated STEM framework.
7. What types of experiences and training have prepared you for teaching within an integrated STEM framework?
8. What resources do you have for teaching integrated STEM?
9. What specific challenges do you think students will have in learning science/math in this manner?
10. What challenges do you anticipate experiencing in teaching in an integrated STEM framework?
11. What type of support do you feel is necessary in order to teach within an integrated STEM framework?

APPENDIX B

Electronic Survey

Consent and Confidentiality Statements for Electronically-Delivered Survey The purpose of this research project is to understand how teachers feel about STEM teaching in general as well as in their own ability to teach STEM lessons. This is a research project being conducted by a graduate student at The University of Tennessee for a doctoral dissertation. You have been invited to participate in this research project because you are a science teacher in the School District and your beliefs and opinions are highly valued. Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time. If you decide not to participate in this study or if you withdraw from participating at any time, you will not be penalized in any way. The procedure involves filling an online survey that will take approximately 15 minutes. Your responses will be confidential and no identifying information such as your name, email address or IP address will be collected. The survey questions will be about your understanding of STEM education and your beliefs about your abilities to teach STEM lessons as well as the resources and support you would or do need to successfully teach in a STEM framework. We are committed to keeping your information confidential. All data are stored in a password protected electronic format. To help protect your confidentiality, the surveys will not contain information that will personally identify you or your school. Data collected from the surveys will only be accessible to the primary researcher and her faculty advisor. The results of this study will be used for scholarly purposes only and may be shared with other science education researchers but no identifying information will be accessible. If you have any questions about the research study, please contact Monica Mobley at (865) 245-0085 or monica.mobley@knoxschools.org or the Institutional Review Board at The University of Tennessee Knoxville (865) 974-7697.

This research has been reviewed and approved according to School District's Research and Evaluation Regulations and The University of Tennessee's Institutional Review Board (IRB).

ELECTRONIC CONSENT: Please select your choice below. Clicking on the "agree" button below indicates that:

• you have read the above information
• you voluntarily agree to participate
• you are at least 18 years of age

If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button.

❍ Agree
❍ Disagree

Q1 What is your gender?

- ❍ Male
- ❍ Female

Q2 What is your race?

- ❍ Asian/Pacific Islander
- ❍ Black/African American
- ❍ Hispanic/Latino
- ❍ White/Caucasian
- ❍ Other (please specify below) ____________________

Q3 What grade level do you currently teach? (select all that apply)

- ❑ Pre-K
- ❑ K - 2
- ❑ 3 - 5
- ❑ 6
- ❑ 7 - 8
- ❑ 9 - 10
- ❑ 11 - 12
- ❑ Post Secondary
- ❑ Not currently teaching

Q4 How many years total teaching experience do you have?

- ❍ 0
- ❍ 1 - 2
- ❍ 3 - 5
- ❍ 6 - 10
- ❍ 11 - 15
- ❍ 16 - 20
- ❍ 21 - 29
- ❍ 30+

Q6 How many hours of coursework (your best estimate) outside of science have you taken? (Please type the number in the space provided)

______ Technology
______ Engineering
______ Mathematics

Q7 How many courses (best estimate) outside of science have you taught? (Please type the number in the space provided)

_______ Technology
_______ Engineering
_______ Mathematics
_______ Other (please specify)

Q8 What subjects do you currently teach?

- ❑ Mathematics
- ❑ Science
- ❑ Technology
- ❑ Engineering
- ❑ Other (please specify) ____________________

Q9 In what subjects are you currently licensed?

- ❑ Mathematics
- ❑ Science
- ❑ Technology
- ❑ Engineering
- ❑ Other (please specify) ____________________

Q10 Do you teach any STEM (Science, Technology, Engineering and Mathematics) courses where integrated STEM is the focus?

- ❍ Yes (please specify) ____________________
- ❍ No

Q11 How many years of integrated STEM teaching do you have including this year?

- ❍ 0
- ❍ Less than one
- ❍ 1 - 2
- ❍ 3 - 5
- ❍ 6 - 10
- ❍ 11 - 15
- ❍ 16 - 20
- ❍ 21 - 29
- ❍ 30+

Q12 Does your school/organization include STEM education as one of its mission statements or school-wide priorities?

- Yes
- No

Q13 Does your school/organization include integrated STEM education as one of its mission statements or school-wide priorities?

- Yes
- No

Q16 This section of the questionnaire is designed to help us learn /more about teacher confidence relative to integrated STEM teaching and learning. For each statement below, in response to "I am confident in my ability to..." please respond with a rating of your confidence from "'cannot do at all" to "very confident in my ability to do this"I am confident in my ability to.....

	Cannot do at all	Would have difficulty doing this	Mostly confident I can do this	Very confident that I can do this
Understand what integrated STEM teaching means	❍	❍	❍	❍
Use current knowledge and skills to teach science from within an integrated STEM framework.	❍	❍	❍	❍
Develop knowledge and skills necessary to teach science from within an integrated STEM framework	❍	❍	❍	❍
Use my understanding of integrated STEM in a way that allows me to teach science effectively	❍	❍	❍	❍
Use my teaching experience to teach science effectively from within an integrated STEM framework	❍	❍	❍	❍
Teach my content within an integrated STEM framework	❍	❍	❍	❍

Q17 As with the previous section, please respond with a rating of your confidence in your abilities to perform various teaching tasks from "cannot do at all" to "Very confident that I can do this.

"I am confident in my ability to.....

	Cannot do at all	Would have difficulty doing this	Mostly confident that I can do this	Very confident that I can do this
Use my understanding of cross-cutting concepts to better teach science from within an integrated STEM framework	❍	❍	❍	❍
Overcome challenges of teaching multiple disciplines at once	❍	❍	❍	❍
Overcome challenges related to teaching in new ways	❍	❍	❍	❍
Learn new technologies that will enable me to teach from within an integrated STEM framework	❍	❍	❍	❍
Adapt to new teaching situations such as those necessary to teach science from within an integrated STEM framework	❍	❍	❍	❍
Access technology to teach science from within an integrated STEM framework	❍	❍	❍	❍

Q18 As with the previous section, please respond with a rating of your confidence in your abilities to perform various teaching tasks from "cannot do at all" to "Very confident that I can do this.

"I am confident in my ability to.....

	Cannot do at all	Would have difficulty doing this	Mostly confident that I can do this	Very confident that I can do this
Overcome challenges such as teaching science from within an integrated STEM framework	❍	❍	❍	❍
Use technology to teach science from within an integrated STEM framework	❍	❍	❍	❍
Obtain the materials/resources necessary to teach STEM in an integrated way	❍	❍	❍	❍
Get students to learn standards-based science content while participating in integrated STEM activities	❍	❍	❍	❍
Get students to become interested in STEM careers through participation in integrated STEM learning	❍	❍	❍	❍
Collaborate effectively with other teachers in planning integrated STEM activities	❍	❍	❍	❍

Q19 As with the previous section, please respond with a rating of your confidence in your abilities to perform various teaching tasks from "cannot do at all" to "Very confident that I can do this.

"I am confident in my ability to.....

	Cannot do at all	Would have difficulty doing this	Mostly confident that I can do this	Very confident that I can do this
Foster student enthusiasm for STEM disciplines while teaching in an integrated STEM framework	❍	❍	❍	❍
Access resources necessary to teach science within an integrated STEM framework	❍	❍	❍	❍
Provide my students with technology to engage in learning within an integrated STEM framework	❍	❍	❍	❍
Meet evaluation requirements while teaching integrated STEM	❍	❍	❍	❍
Find professional development programs to acquire knowledge and skills for teaching integrated STEM	❍	❍	❍	❍
Elicit support from my supervisors (principals, administrators, school district) to teach integrated STEM effectively	❍	❍	❍	❍

Q20 As with the previous section, please respond with a rating of your confidence in your abilities to perform various teaching tasks from "cannot do at all" to "Very confident that I can do this." I am confident in my ability to.....

	Cannot do at all	Would have difficulty doing this	Mostly confident that I can do this	Very confident that I can do this
Connect science concepts to those of engineering, mathematics, and technology	❍	❍	❍	❍
Formatively assess student learning of discipline-specific content while teaching integrated STEM	❍	❍	❍	❍
Promote students' grade-level appropriate acquisition of core engineering knowledge	❍	❍	❍	❍
Earn acceptable teacher-evaluation/performance scores despite teaching science in an integrated manner	❍	❍	❍	❍
Get students to experience excitement, interest, and motivation to learn about phenomena in the natural world.	❍	❍	❍	❍
Develop summative assessments to measure students' integrated knowledge of STEM at the end of an instructional unit.	❍	❍	❍	❍

Q21 Please type your opinion regarding the question, "What do you think are the biggest challenges facing science teachers in integrated STEM teaching and learning environments? "

APPENDIX C

Table 16: *Race*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Male	47	24.1	24.2	24.2
	Female	147	75.4	75.8	100.0
	Total	194	99.5	100.0	
Missing	System	1	.5		
Total		195	100.0		

Table 17: *Race/Ethnicity*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Asian/PI	5	2.6	2.6	2.6
	Black/AA	15	7.7	7.8	10.4
	Hisp/Latino	5	2.6	2.6	13.0
	White/Cau	168	86.2	87.0	100.0
	Total	193	99.0	100.0	
Missing	System	2	1.0		
Total		195	100.0		

Table 18: *Grades Taught - PreK*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	No	191	97.9	98.5	98.5
	Yes	3	1.5	1.5	100.0
	Total	194	99.5	100.0	
Missing	System	1	.5		
Total		195	100.0		

Table 19: *Grades Taught K-2*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	No	189	96.9	97.4	97.4
	Yes	5	2.6	2.6	100.0
	Total	194	99.5	100.0	
Missing	System	1	.5		
Total		195	100.0		

Table 20: *Grades Taught 3-5*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	No	178	91.3	91.8	91.8
	Yes	16	8.2	8.2	100.0
	Total	194	99.5	100.0	
Missing	System	1	.5		
Total		195	100.0		

Table 21: *Grades Taught 6*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	No	149	76.4	76.8	76.8
	Yes	45	23.1	23.2	100.0
	Total	194	99.5	100.0	
Missing	System	1	.5		
Total		195	100.0		

Table 22: *Grades Taught 9-10*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	No	115	59.0	59.3	59.3
	Yes	79	40.5	40.7	100.0
	Total	194	99.5	100.0	
Missing	System	1	.5		
Total		195	100.0		

Table 23: *Grades Taught 11-12*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	No	122	62.6	62.9	62.9
	Yes	72	36.9	37.1	100.0
	Total	194	99.5	100.0	
Missing	System	1	.5		
Total		195	100.0		

Table 24: *Grades Taught - Post Secondary*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	No	171	87.7	88.1	88.1
	Yes	23	11.8	11.9	100.0
	Total	194	99.5	100.0	
Missing	System	1	.5		
Total		195	100.0		

Table 25: *Grades Taught - Not Currently Teaching*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	No	167	85.6	86.1	86.1
	Yes	27	13.8	13.9	100.0
	Total	194	99.5	100.0	
Missing	System	1	.5		
Total		195	100.0		

Table 26: *Years of Teaching Experience*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	<1	16	8.2	8.3	8.3
	1-2	15	7.7	7.8	16.1
	3-5	24	12.3	12.5	28.6
	6-10	41	21.0	21.4	50.0
	11-15	33	16.9	17.2	67.2
	16-20	18	9.2	9.4	76.6
	21-29	25	12.8	13.0	89.6
	30+	20	10.3	10.4	100.0
	Total	192	98.5	100.0	
Missing	System	3	1.5		
Total		195	100.0		

Table 27: *Hours of Technology Coursework Taken*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	0	63	32.3	33.9	33.9
	2	3	1.5	1.6	35.5
	3	22	11.3	11.8	47.3
	4	4	2.1	2.2	49.5
	5	4	2.1	2.2	51.6
	6	25	12.8	13.4	65.1
	7	1	.5	.5	65.6
	8	9	4.6	4.8	70.4
	9	6	3.1	3.2	73.7
	10	9	4.6	4.8	78.5
	12	9	4.6	4.8	83.3
	15	5	2.6	2.7	86.0
	18	6	3.1	3.2	89.2
	20	8	4.1	4.3	93.5
	24	2	1.0	1.1	94.6
	25	1	.5	.5	95.2
	30	3	1.5	1.6	96.8
	40	2	1.0	1.1	97.8
	45	1	.5	.5	98.4
	50	1	.5	.5	98.9
	100	1	.5	.5	99.5
	120	1	.5	.5	100.0
	Total	186	95.4	100.0	
Missing	System	9	4.6		
Total		195	100.0		

Table 28: *Hours of Math Coursework Taken*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	0	32	16.4	17.2	17.2
	1	1	.5	.5	17.7
	2	1	.5	.5	18.3
	3	8	4.1	4.3	22.6
	4	3	1.5	1.6	24.2
	5	1	.5	.5	24.7
	6	15	7.7	8.1	32.8
	8	9	4.6	4.8	37.6
	9	14	7.2	7.5	45.2
	10	9	4.6	4.8	50.0
	12	33	16.9	17.7	67.7
	13	1	.5	.5	68.3
	14	1	.5	.5	68.8
	15	11	5.6	5.9	74.7
	16	4	2.1	2.2	76.9
	17	1	.5	.5	77.4
	18	4	2.1	2.2	79.6
	20	12	6.2	6.5	86.0
	21	2	1.0	1.1	87.1
	24	4	2.1	2.2	89.2
	25	4	2.1	2.2	91.4
	27	1	.5	.5	91.9
	30	7	3.6	3.8	95.7
	36	3	1.5	1.6	97.3
	40	1	.5	.5	97.8
	45	1	.5	.5	98.4
	46	1	.5	.5	98.9
	60	2	1.0	1.1	100.0
	Total	186	95.4	100.0	
Missing	System	9	4.6		
Total		195	100.0		

Table 29: *Hours of Engineering Coursework Taken*

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
hrs_Tech	186	0	120	8.01	13.856
hrs_Math	186	0	60	12.03	10.639
hrs_Eng	185	0	250	6.03	22.594
Valid N (listwise)	184				

Table 30: *Number of Courses Taught in Technology*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	0	148	75.9	80.4	80.4
	1	13	6.7	7.1	87.5
	2	6	3.1	3.3	90.8
	3	7	3.6	3.8	94.6
	4	4	2.1	2.2	96.7
	5	2	1.0	1.1	97.8
	6	1	.5	.5	98.4
	8	1	.5	.5	98.9
	12	2	1.0	1.1	100.0
	Total	184	94.4	100.0	
Missing	System	11	5.6		
Total		195	100.0		

Table 31: *Number of Courses Taught in Engineering*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	0	161	82.6	88.0	88.0
	1	11	5.6	6.0	94.0
	2	2	1.0	1.1	95.1
	3	3	1.5	1.6	96.7
	4	1	.5	.5	97.3
	5	1	.5	.5	97.8
	6	1	.5	.5	98.4
	10	2	1.0	1.1	99.5
	12	1	.5	.5	100.0
	Total	183	93.8	100.0	
Missing	System	12	6.2		
Total		195	100.0		

Table 32: *Number of Courses Taught in Mathematics*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	0	127	65.1	69.4	69.4
	1	27	13.8	14.8	84.2
	2	4	2.1	2.2	86.3
	3	4	2.1	2.2	88.5
	4	4	2.1	2.2	90.7
	5	4	2.1	2.2	92.9
	6	4	2.1	2.2	95.1
	7	1	.5	.5	95.6
	8	1	.5	.5	96.2
	13	1	.5	.5	96.7
	15	1	.5	.5	97.3
	18	1	.5	.5	97.8
	23	1	.5	.5	98.4
	40	1	.5	.5	98.9
	48	1	.5	.5	99.5
	50	1	.5	.5	100.0
	Total	183	93.8	100.0	
Missing	System	12	6.2		
Total		195	100.0		

Table 33: *Number of Courses Taught in Non-STEM Disciplines*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	0	154	79.0	83.7	83.7
	1	11	5.6	6.0	89.7
	2	2	1.0	1.1	90.8
	3	2	1.0	1.1	91.8
	4	3	1.5	1.6	93.5
	5	1	.5	.5	94.0
	6	6	3.1	3.3	97.3
	8	3	1.5	1.6	98.9
	10	1	.5	.5	99.5
	15	1	.5	.5	100.0
	Total	184	94.4	100.0	
Missing	System	11	5.6		
Total		195	100.0		

Table 34: *Number of Courses "Non-Science" Taught*

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
crstaught_Tech	184	0	12	.60	1.712
crstaught_Eng	183	0	12	.39	1.554
crstaught_Math	183	0	50	1.80	6.445
crstaught_Other	184	0	15	.67	2.039
Valid N (listwise)	182				

Table 35: *Number of Teachers Licensed in Science*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	no	69	35.4	35.6	35.6
	yes	125	64.1	64.4	100.0
	Total	194	99.5	100.0	
Missing	System	1	.5		
Total		195	100.0		

Table 36: *Number of Teachers Licensed in Technology*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	no	184	94.4	95.3	95.3
	yes	9	4.6	4.7	100.0
	Total	193	99.0	100.0	
Missing	System	2	1.0		
Total		195	100.0		

Table 37: *Number of Teachers Licensed in Engineering*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	no	180	92.3	93.3	93.3
	yes	13	6.7	6.7	100.0
	Total	193	99.0	100.0	
Missing	System	2	1.0		
Total		195	100.0		

Table 38: *Number of Teachers Licensed in Mathematics*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	no	132	67.7	68.4	68.4
	yes	61	31.3	31.6	100.0
	Total	193	99.0	100.0	
Missing	System	2	1.0		
Total		195	100.0		

Table 39: *Number of Teachers Teaching Integrated STEM Courses*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	yes	60	30.8	31.1	31.1
	no	133	68.2	68.9	100.0
	Total	193	99.0	100.0	
Missing	System	2	1.0		
Total		195	100.0		

Table 40: *Years of STEM Teaching Experience*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	0	108	55.4	59.0	59.0
	<1	16	8.2	8.7	67.8
	1-2	32	16.4	17.5	85.2
	3-5	17	8.7	9.3	94.5
	6-10	6	3.1	3.3	97.8
	11-15	1	.5	.5	98.4
	16-20	3	1.5	1.6	100.0
	Total	183	93.8	100.0	
Missing	System	12	6.2		
Total		195	100.0		

Table 41: *Number of Teachers in Schools with STEM Mission*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	yes	75	38.5	41.0	41.0
	no	108	55.4	59.0	100.0
	Total	183	93.8	100.0	
Missing	System	12	6.2		
Total		195	100.0		

Table 42: *Number of Teachers in Schools with Integrated STEM Mission*

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	yes	68	34.9	37.2	37.2
	no	115	59.0	62.8	100.0
	Total	183	93.8	100.0	
Missing	System	12	6.2		
Total		195	100.0		

APPENDIX D

Table 43: *Mean Item Responses*

Item Number	N	Minimum	Maximum	Mean	Std. Deviation
29	175	2	4	3.30	.590
10	177	1	4	3.29	.724
11	177	1	4	3.27	.687
9	177	1	4	3.25	.672
18	177	1	4	3.23	.705
26	174	1	4	3.17	.649
19	177	1	4	3.16	.689
3	181	1	4	3.15	.749
17	177	1	4	3.11	.722
8	178	1	4	3.11	.736
14	176	1	4	3.09	.724
13	177	1	4	3.08	.690
28	175	1	4	3.08	.690
12	169	1	4	3.06	.814
1	183	1	4	3.04	.776
22	176	1	4	3.03	.724
16	175	1	4	3.02	.711
4	182	1	4	3.02	.786
23	177	1	4	3.00	.754

Table 43: *Mean Item Responses Continued*

Item Number	N	Minimum	Maximum	Mean	Std. Deviation
6	179	1	4	2.99	.757
25	175	1	4	2.97	.738
5	182	1	4	2.97	.750
2	182	1	4	2.96	.723
20	176	1	4	2.95	.770
30	166	1	4	2.94	.694
24	176	1	4	2.93	.771
21	176	1	4	2.92	.796
27	175	1	4	2.86	.753
7	177	1	4	2.85	.777
15	177	1	4	2.85	.787
Valid N (listwise)	156				

APPENDIX E

Table 44: *KMO and Bartlett's - Initial*

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.939
Bartlett's Test of Sphericity	Approx. Chi-Square	3818.865
	df	435
	Sig.	.000

Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity on Initial Factor Analysis using Maximum Likelihood Extraction.

Table 45: *Communalities After Initial Extraction*

	Initial	Extraction
Use Current Knowledge and Skills	.771	.709
Develop New Knowledge and Skills	.704	.656
Use Understanding of iSTEM to teach	.757	.699
Use Teaching Experience	.842	.853
Teach Content	.764	.719
Meet Evaluation Requirements	.669	.508
Formatively Assess Students	.722	.624
Connect Concepts	.658	.611
Promote Eng. Aquisition	.685	.600
Earn Acceptable Eval/Peformance Scores	.713	.570
Get Students Excited	.645	.498
Develop Summative Assessment	.688	.603
Use Understanding of What iSTEM means	.733	.642
Use Cross-Cutting Techniques	.597	.482
Overcome Challenges 1	.621	.506
Overcome Challenges 2	.738	.684
Learn New Technologies	.765	.808
Adapt to New Teaching Situations	.792	.725
Access Technology	.721	.588
Overcome Pedagogical Challenges	.731	.661
Use Technology	.738	.665
Obtain Materials	.693	.649
Learn Standards and Content	.701	.629
Become Interested in STEM Careers	.685	.537
Collaborate with STEM Teachers	.632	.526
Foster Student Enthusiasm	.712	.567
Access Resources	.731	.738
Use Available Resources	.687	.664
Find Professional Development	.592	.504
Elicit Support	.508	.367

Extraction Method: Maximum Likelihood.

Table 46: *Communalities after Removal of "Elicit Support"*

	Initial	*Extraction*
PKS_UseKnowSkills	.769	.713
PKS_DevelopnewK&S	.705	.660
CNT_UseUnderstd	.759	.703
PKS_UseTchExp	.843	.848
CNT_TchContent	.765	.718
PROF_meetevalreq	.665	.516
STU_formassess	.721	.632
CNT_connectconcepts	.661	.616
STU_promoteenthus	.687	.584
PROF_earnevalscores	.712	.578
STU_getstudexcited	.600	.493
RES_dvlopsummativeassess	.690	.604
PKS_UnderstndIntegSTEMmeans	.736	.645
CNT_CrossCutting	.597	.490
PROF_overcomeChlngs1	.623	.517
PROF_overcomeChlgs2	.737	.691
SUP_learnnewTech	.763	.819
PROF_Adapt	.789	.718
RES_AcessTech	.703	.576
PKS_overcomepedchal	.733	.666
RES_usetech	.724	.648
SUP_obtainmtrls	.687	.652
CNT_learnstandcontent	.704	.633
STU_becomeintrstdcareers	.688	.546
SUP_collabwithSTEMtchrs	.627	.495
STU_fosterenthus	.716	.579
RES_acessresources	.707	.761
RES_useavailresources	.674	.627
SUP_findprofdevelopmt	.584	.504

Extraction: Maximum Likelihood.

Table 47: *Initial Four-Factor Model - Variance Explained*

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	15.689	54.102	54.102	15.288	52.719	52.719	5.518	19.028	19.028
2	1.458	5.028	59.129	1.146	3.950	56.669	5.233	18.046	37.074
3	1.310	4.518	63.648	.961	3.313	59.982	3.908	13.475	50.549
4	1.180	4.070	67.718	.835	2.878	62.861	3.570	12.312	62.861
5	.888	3.062	70.780						
6	.835	2.879	73.659						
7	.708	2.440	76.099						
8	.659	2.272	78.371						
9	.610	2.102	80.473						
10	.523	1.803	82.276						
11	.484	1.668	83.944						
12	.466	1.607	85.550						
13	.420	1.448	86.999						
14	.405	1.395	88.394						
15	.388	1.336	89.731						
16	.357	1.230	90.961						
17	.318	1.096	92.057						
18	.298	1.028	93.085						
19	.285	.984	94.069						
20	.277	.954	95.023						
21	.239	.824	95.847						
22	.232	.800	96.647						
23	.212	.730	97.378						
24	.167	.577	97.955						
25	.149	.515	98.470						
26	.129	.445	98.915						
27	.117	.403	99.318						
28	.103	.354	99.671						
29	.095	.329	100.000						

Extraction Method: Maximum Likelihood.

Table 48: *KMO and Bartlett's Test after Correcting for Complexity*

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.938
Bartlett's Test of Sphericity	Approx. Chi-Square	3743.851
	df	406
	Sig.	.000

Table 49: *Rotated Factor Matrix[a] Showing Complexity*

	Factor			
	1	*2*	*3*	*4*
CNT_connectconcepts	.637	.303		.318
STU_promoteenthus	.633	.318		
STU_formassess	.626	.374		
RES_dvlopsummativeassess	.620	.347		
PROF_earnevalscores	.612			.316
PROF_overcomeChlgs2	.573		.534	
PKS_overcomepedchal	.548	.382	.442	
STU_getstudexcited	.544			
PROF_overcomeChlngs1	.528		.408	
CNT_learnstandcontent	.509	.318	.336	.400
PROF_meetevalreq	.439		.362	.389
PKS_UseTchExp		.801		
CNT_TchContent	.359	.708		
CNT_UseUnderstd	.314	.657		.321
PKS_UseKnowSkills		.654		.365
PKS_DevelopnewK&S		.640	.360	
PKS_UnderstndIntegSTEMmeans	.374	.561		.406
STU_fosterenthus	.441	.517		
STU_becomeintrstdcareers	.409	.462	.359	
CNT_CrossCutting	.429	.447		
SUP_collabwithSTEMtchrs		.410	.344	.402
SUP_learnnewTech			.860	
PROF_Adapt	.369	.387	.636	
RES_usetech		.336	.601	
RES_AcessTech			.599	.346
RES_acessresources	.302			.759
SUP_obtainmtrls	.332			.660
RES_useavailresources		.387		.619
SUP_findprofdevelopmt	.405			.475

Extraction Method: Maximum Likelihood. Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 7 iterations.

Table 50: *KMO and Bartlett's Test for Three-Factor Model*

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.930
Bartlett's Test of Sphericity	Approx. Chi-Square	2235.495
	df	171
	Sig.	.000

Total Variance Explained for Three Factor Model

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Factor	Total	% of Variance	Cumul. %	Total	% of Variance	Cumul. %	Total	% of Variance	Cumul. %
1	10.32	54.354	54.354	9.830	51.738	51.738	5.062	26.644	26.644
2	1.333	7.017	61.372	.896	4.714	56.452	3.600	18.946	45.590
3	1.114	5.861	67.232	.991	5.215	61.667	3.055	16.077	61.667
4	.968	5.097	72.329						
5	.794	4.180	76.509						
6	.575	3.026	79.535						
7	.502	2.643	82.179						
8	.446	2.347	84.525						
9	.429	2.259	86.784						
10	.379	1.996	88.780						
11	.342	1.801	90.581						
12	.330	1.737	92.317						
13	.296	1.557	93.874						
14	.259	1.365	95.239						
15	.243	1.281	96.520						
16	.200	1.055	97.574						
17	.185	.975	98.549						
18	.146	.767	99.316						
19	.130	.684	100.000						

Extraction Method: Maximum Likelihood.

Table 51: *KMO and Bartlett's Test for Two-Factor Model*

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.924
Bartlett's Test of Sphericity	Approx. Chi-Square	1733.624
	df	120
	Sig.	.000

Table 52: *Total Variance Explained for Two-Factor Model*

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumul. %	Total	% of Variance	Cumul. %	Total	% of Variance	Cumul. %
1	8.680	54.247	54.247	8.081	50.507	50.507	5.481	34.259	34.259
2	1.191	7.445	61.692	.835	5.218	55.725	3.435	21.466	55.725
3	.977	6.108	67.799						
4	.876	5.472	73.271						
5	.741	4.628	77.900						
6	.558	3.487	81.387						
7	.453	2.834	84.221						
8	.418	2.610	86.831						
9	.379	2.369	89.200						
10	.353	2.208	91.408						
11	.306	1.913	93.321						
12	.285	1.778	95.100						
13	.247	1.541	96.641						
14	.213	1.333	97.974						
15	.181	1.134	99.107						
16	.143	.893	100.000						

Extraction Method: Maximum Likelihood.

APPENDIX F

Table 53*: Item Total Statistics for Factor 1 - Social*

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Connect Concepts	26.86	24.441	.722	.608	.907
Promote Eng. Knowledge Acquisition	27.14	24.023	.697	.581	.909
Develop Summative Assessments	27.07	24.168	.722	.586	.907
Develop Formative Assessments	27.08	23.789	.724	.599	.907
Earn Acceptable Evaluation/Performance Scores	26.93	24.355	.709	.569	.908
Access Resources	27.07	23.609	.718	.636	.907
Obtain Materials	27.20	23.728	.682	.566	.910
Get Students Excited	26.72	25.432	.637	.460	.912
Use available Resources	27.13	23.915	.666	.505	.911
Meet Evaluation Requirements	27.01	24.317	.661	.563	.911

Table 54: *Item-Total Statistics for Factor 2 - Personal*

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Use Teaching Experience	12.15	6.849	.847	.750	.888
Teach Content	12.13	7.157	.741	.629	.909
Use Knowledge and Skills	12.17	7.022	.817	.704	.895
Use Understanding of iSTEM	12.10	6.837	.788	.659	.900
Develop New Knowledge and Skills	11.97	7.151	.757	.608	.906

Table 55: *Item Total Statistics for Factor 3 - Material*

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Learn New Technologies	9.40	3.782	.742	.563	.842
Adapt to New Teaching Situations	9.40	3.879	.765	.586	.835
Access Technology	9.61	3.537	.717	.522	.856
Use Technology	9.59	3.855	.737	.547	.844

APPENDIX G

Final SETIS Instrument

Please respond with a rating of your confidence in your abilities to perform various teaching tasks from "cannot do at all" to "Very confident that I can do this.

"I am confident in my ability to.....

Item#	**Item**	**Cannot do at all 1**	**Would have difficulty doing this 2**	**Mostly confident I can do this 3**	**Very confident I can do this 4**
1	connect science concepts to those of engineering, mathematics, and technology				
2	promote students grade-level appropriate acquisition of core engineering knowledge				
3	develop summative assessments to measure students' integrated knowledge of STEM at the end of an instructional unit				
4	develop formative assessments to measure student learning of discipline-specific content while teaching integrated STEM				
5	earn acceptable teacher-evaluation/performance scores while teaching science in an integrated STEM framework				
6	Access resources necessary to teach science within an integrated STEM framework				
7	Obtain the materials necessary to teach science through STEM in an integrated way				
8	Get students to experience excitement, interest, and motivation to learn about phenomena in the natural world				
9	Use currently available resources to provide my students with technology to engage in learning within an integrated STEM framework				

Item#	Item	Cannot do at all 1	Would have difficulty doing this 2	Mostly confident I can do this 3	Very confident I can do this 4
10	Meet evaluation requirements while teaching integrated STEM				
11	Use my teaching experience to teach science effectively from within an integrated STEM framework				
12	Teach my content within an integrated STEM framework				
13	Use current knowledge and skills to teach science within an integrated STEM framework				
14	Use my understanding of integrated STEM in a way that allows me to teach science effectively				
15	Develop new knowledge and skills necessary to teach science from within an integrated STEM framework				
16	Learn new technologies that will enable me to teach from within an integrated STEM framework				
17	Adapt to new teaching situations such as those necessary to teach science from within an integrated STEM framework				
18	Use currently available resources to provide my students with technology to engage in learning within an integrated STEM framework				
19	Access technology to teach science from within and integrated STEM framework				

APPENDIX H

Table 56: *Pearson Correlation Coefficients*

	PKS_Us	PKS_Developne	CNT_UseU	PKS_Us	CNT	PROF_mee	STU_fo	CNT	STU	PROF_earn
PKS_UseKnowSkills	1.000	.745	.752	.748	.650	.515	.534	.540	.493	.494
PKS_DevelopnewK&S	.745	1.000	.652	.725	.651	.439	.519	.488	.464	.461
CNT_UseUnderstd	.752	.652	1.000	.761	.642	.501	.594	.532	.531	.484
PKS_UseTchExp	.748	.725	.761	1.000	.831	.494	.578	.520	.541	.492
CNT_TchContent	.650	.651	.642	.831	1.000	.428	.554	.509	.514	.490
PROF_meetevalreq	.515	.439	.501	.494	.428	1.000	.600	.369	.411	.662
STU_formassess	.534	.519	.594	.578	.554	.600	1.000	.585	.537	.639
CNT_connectconcepts	.540	.488	.532	.520	.509	.369	.585	1.000	.671	.540
STU_promoteenthus	.493	.464	.531	.541	.514	.411	.537	.671	1.000	.549
PROF_earnevalscores	.494	.461	.484	.492	.490	.662	.639	.540	.549	1.000
STU_getstudexcited	.469	.460	.545	.495	.480	.438	.512	.546	.615	.487
RES_dvlopsummativeassess	.551	.556	.521	.572	.522	.478	.663	.654	.632	.589
PKS_UnderstndIntegSTEMmea	.706	.574	.694	.661	.608	.486	.602	.529	.494	.614
CNT_CrossCutting	.501	.503	.592	.607	.577	.447	.543	.519	.480	.428
PROF_overcomeChlngs1	.485	.465	.399	.460	.529	.426	.464	.517	.472	.457
PROF_overcomeChlgs2	.482	.498	.504	.444	.503	.583	.542	.545	.506	.598
SUP_learnnewTech	.479	.523	.471	.454	.403	.521	.426	.318	.313	.413
PROF_Adapt	.534	.550	.604	.595	.577	.474	.541	.517	.435	.503
RES_AcessTech	.524	.505	.474	.493	.497	.465	.375	.396	.410	.388
PKS_overcomepedchal	.567	.619	.567	.632	.575	.582	.648	.527	.541	.579
RES_usetech	.594	.630	.548	.570	.564	.474	.496	.509	.526	.500
SUP_obtainmtrls	.572	.451	.525	.543	.502	.524	.478	.577	.501	.494
CNT_learnstandcontent	.570	.551	.575	.560	.602	.553	.533	.574	.549	.574
STU_becomeintrstdcareers	.570	.531	.598	.592	.552	.448	.584	.495	.570	.399
SUP_collabwithSTEMtchrs	.501	.526	.533	.541	.508	.376	.458	.455	.323	.369
STU_fosterenthus	.595	.582	.592	.626	.638	.483	.636	.529	.529	.434
RES_acessresources	.574	.468	.563	.559	.479	.580	.504	.553	.519	.531
RES_useavailresources	.588	.474	.592	.564	.494	.484	.494	.498	.460	.498
SUP_findprofdevelopmt	.523	.457	.472	.530	.473	.575	.580	.474	.435	.495
SUP_elicitsupport	.334	.357	.403	.382	.382	.391	.474	.470	.428	.472

Table 56: *Pearson Correlation Coefficients (Continued)*

	STU_getstudexcited	RES_dvlopsummativeassess	PKS_UnderstndIntegSTEMmeans	CNT_CrossCutting	PROF_overcomeChlng	PROF_overcomeChlgs2	SUP_learnnewTech	PROF_Adapt	RES_AcessTech	PKS_overcomepedchal
PKS_UseKnowSkills	.469	.551	.706	.501	.485	.482	.479	.534	.524	.567
PKS_DevelopnewK&S	.460	.556	.574	.503	.465	.498	.523	.550	.505	.619
CNT_UseUnderstd	.545	.521	.694	.592	.399	.504	.471	.604	.474	.567
PKS_UseTchExp	.495	.572	.661	.607	.460	.444	.454	.595	.493	.632
CNT_TchContent	.480	.522	.608	.577	.529	.503	.403	.577	.497	.575
PROF_meetevalreq	.438	.478	.486	.447	.426	.583	.521	.474	.465	.582
STU_formassess	.512	.663	.602	.543	.464	.542	.426	.541	.375	.648
CNT_connectconcepts	.546	.654	.529	.519	.517	.545	.318	.517	.396	.527
STU_promoteenthus	.615	.632	.494	.480	.472	.506	.313	.435	.410	.541
PROF_earnevalscores	.487	.589	.614	.428	.457	.598	.413	.503	.388	.579
STU_getstudexcited	1.000	.509	.459	.413	.373	.530	.426	.505	.381	.494
RES_dvlopsummativeassess	.509	1.000	.564	.539	.549	.493	.389	.535	.403	.555
PKS_UnderstndIntegSTEMmea	.459	.564	1.000	.568	.406	.453	.335	.568	.482	.527
CNT_CrossCutting	.413	.539	.568	1.000	.509	.566	.385	.533	.513	.518
PROF_overcomeChlngs1	.373	.549	.406	.509	1.000	.668	.499	.565	.540	.575
PROF_overcomeChlgs2	.530	.493	.453	.566	.668	1.000	.630	.619	.548	.661
SUP_learnnewTech	.426	.389	.335	.385	.499	.630	1.000	.722	.619	.588
PROF_Adapt	.505	.535	.568	.533	.565	.619	.722	1.000	.688	.648
RES_AcessTech	.381	.403	.482	.513	.540	.548	.619	.688	1.000	.408
PKS_overcomepedchal	.494	.555	.527	.518	.575	.661	.588	.648	.408	1.000
RES_usetech	.493	.572	.557	.430	.522	.600	.684	.684	.610	.634
SUP_obtainmtrls	.495	.507	.552	.459	.498	.529	.378	.440	.499	.533
CNT_learnstandcontent	.541	.560	.549	.511	.591	.613	.459	.592	.513	.613
STU_becomeintrstdcareers	.571	.472	.540	.501	.441	.458	.525	.605	.461	.583
SUP_collabwithSTEMtchrs	.351	.396	.578	.489	.358	.470	.435	.599	.484	.519
STU_fosterenthus	.603	.463	.615	.473	.417	.480	.369	.563	.437	.575
RES_acessresources	.480	.507	.571	.437	.425	.524	.366	.474	.444	.501
RES_useavailresources	.406	.487	.610	.465	.369	.427	.337	.467	.564	.416
SUP_findprofdevelopmt	.502	.500	.512	.398	.377	.471	.385	.446	.373	.463
SUP_elicitsupport	.573	.401	.408	.390	.343	.410	.332	.427	.422	.426

Table 56: *Pearson Correlation Coefficients (Continued)*

	RES_usetech	SUP_obtainmtrls	CNT_learnstandcontent	STU_becomeintrstdcareers	SUP_collabwithSTEMt	STU_fosterenthus	RES_acessresources	RES_useavailresource	SUP_findprofdevelopm	SUP_elicitsupport
PKS UseKnowSkills	.594	.572	.570	.570	.501	.595	.574	.588	.523	.334
PKS_DevelopnewK&S	.630	.451	.551	.531	.526	.582	.468	.474	.457	.357
CNT_UseUnderstd	.548	.525	.575	.598	.533	.592	.563	.592	.472	.403
PKS_UseTchExp	.570	.543	.560	.592	.541	.626	.559	.564	.530	.382
CNT_TchContent	.564	.502	.602	.552	.508	.638	.479	.494	.473	.382
PROF_meetevalreq	.474	.524	.553	.448	.376	.483	.580	.484	.575	.391
STU_formassess	.496	.478	.533	.584	.458	.636	.504	.494	.580	.474
CNT_connectconcepts	.509	.577	.574	.495	.455	.529	.553	.498	.474	.470
STU_promoteenthus	.526	.501	.549	.570	.323	.529	.519	.460	.435	.428
PROF_earnevalscores	.500	.494	.574	.399	.369	.434	.531	.498	.495	.472
STU_getstudexcited	.493	.495	.541	.571	.351	.603	.480	.406	.502	.573
RES_dvlopsummativeassess	.572	.507	.560	.472	.396	.463	.507	.487	.500	.401
PKS_UnderstndIntegSTEMmea	.557	.552	.549	.540	.578	.615	.571	.610	.512	.408
CNT_CrossCutting	.430	.459	.511	.501	.489	.473	.437	.465	.398	.390
PROF_overcomeChlngs1	.522	.498	.591	.441	.358	.417	.425	.369	.377	.343
PROF_overcomeChlgs2	.600	.529	.613	.458	.470	.480	.524	.427	.471	.410
SUP_learnnewTech	.684	.378	.459	.525	.435	.369	.366	.337	.385	.332
PROF_Adapt	.684	.440	.592	.605	.599	.563	.474	.467	.446	.427
RES_AcessTech	.610	.499	.513	.461	.484	.437	.444	.564	.373	.422
PKS_overcomepedchal	.634	.533	.613	.583	.519	.575	.501	.416	.463	.426
RES_usetech	1.000	.524	.644	.569	.568	.554	.479	.549	.421	.370
SUP_obtainmtrls	.524	1.000	.659	.469	.498	.469	.728	.581	.580	.490
CNT_learnstandcontent	.644	.659	1.000	.613	.553	.577	.599	.536	.557	.441
STU_becomeintrstdcareers	.569	.469	.613	1.000	.536	.669	.437	.497	.437	.380
SUP_collabwithSTEMtchrs	.568	.498	.553	.536	1.000	.515	.548	.617	.464	.416
STU_fosterenthus	.554	.469	.577	.669	.515	1.000	.554	.513	.480	.388
RES_acessresources	.479	.728	.599	.437	.548	.554	1.000	.683	.628	.414
RES_useavailresources	.549	.581	.536	.497	.617	.513	.683	1.000	.485	.435
SUP_findprofdevelopmt	.421	.580	.557	.437	.464	.480	.628	.485	1.000	.487
SUP_elicitsupport	.370	.490	.441	.380	.416	.388	.414	.435	.487	1.000

VITA

Monica Clutch Mobley was born in Bozeman, MT to David Chappell Clutch and Mary Jane Blossom Clutch. Second in birth order, Monica was one of three sons and two daughters. She attended multiple schools in multiple states having grown up in a military family – her father had a 20-year career in the Navy. Monica graduated from Craigmont High School in Memphis, TN in 1991. After graduation Monica pursued a lifelong dream of a degree in biology with a focus on conservation and wildlife management. She received a Bachelor of Science degree in Natural Resources Management/Wildlife Biology from the University of Tennessee at Martin in 1994 followed by a Master of Science degree in Biology from Murray State University in Murray, KY, in 2002. Having learned that she had a strong interest in science education, Monica earned a Master of Science in Education from the University of Tennessee at Martin in 2005. After five years as the West Tennessee Program Manager with The Nature Conservancy, Monica accepted a graduate teaching assistantship at The University of Tennessee, Knoxville in the Department of Theory and Practice in Teacher Education. Monica graduated from the University of Tennessee with a Doctor of Philosophy Degree in May, 2015, in that field of study, specializing in science teacher education specifically directed at STEM teacher education.